2012 Research Portfolio

Research Offerings to Shape the Future of Electricity
Environment

Bringing together research and analysis in science, technology, and health to make the production and use of energy sustainable for current and future generations

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Program Overview

Program Description

The Clean Air Act requires the U.S. Environmental Protection Agency (EPA) to determine whether and to what degree to regulate hazardous air pollutants (HAPs, or air toxics) emitted by power plants. Following numerous studies, regulatory proposals, and court challenges, EPA issued a draft maximum achievable control technology (MACT) standard in early 2011, scheduled for final form by the end of 2011. The ruling by EPA, based solely on achievable control standards, nonetheless sets the stage for future, risk-based regulation of utility HAPs after its MACT standards have been achieved. These “residual risk” requirements are presaged by EPA statements that the MACT rule itself is necessary but not sufficient to reduce HAPs risks to acceptable levels. This evolution of HAPs regulations, along with more-stringent EPA health standards, sets the background for applying emerging research results as well as innovative analysis methods to these issues. The goal is to ensure that the latest and best science is considered in all future decision making, domestically and internationally. The issuance and implementation of a utility MACT rule is the start of a host of new health risk issues. In particular, the concerns over urban air toxics, residual risk, international toxics agreements, and new health research will require scientific diligence to continue.

The Electric Power Research Institute's (EPRI’s) Air and Multimedia Toxics Health and Risk Assessment program provides a comprehensive, stakeholder-oriented approach to technical and policy-related issues. The program is regarded by industry and public agencies as a critical and highly regarded source of scientific information on air and multimedia toxics. The research examines all aspects of trace substances, including HAPs, across multiple environmental media (air, land, and water). The program conducts basic health science research to address cutting-edge questions on health effects and public health risk assessment of numerous potentially toxic substances, including mercury, arsenic, lead, acid gases, selenium, nickel, chromium, cadmium, and dioxins and other organics.

Research Value

The program’s basic studies of air toxics health effects via all environmental and exposure routes inform other research programs within and beyond EPRI. In addition, the program carries out integrative studies of toxics from all global sources via air and other pathways through environmental cycling to human exposure and human health risk assessment. An important and growing effort is examining the health impacts of complex exposures to ranges of chemical mixtures, such as both mercury and lead, with common health effect endpoints. The program objectives allow it to provide forward-looking insight into developing federal, state, and international regulatory considerations. Such anticipatory wide-ranging exploratory research allows

- representation of a broader stakeholder research perspective as issues emerge;
- independent scientific analyses that inform regulators and the public and broaden the perspective on the technical consequences of future actions, including regulation; and
- provision of a framework for balanced, informed planning and decision making based on more-complete data and analyses.

Approach

EPRI’s Air Toxics program provides a key component in an integrated approach to environmental planning for power companies. The work is carried out through case studies and industrywide national and international assessments of environmental impacts for both current and future operations. Publicly proposed regulatory steps undergo technical review to assess resulting changes in toxics concentrations and health effects. The program staff has established direct and frequent research links with federal and state agencies to exchange data and findings, as well as undertaking cooperative research efforts to fill vital information gaps. Frequent briefings to federal and state executive departments and congressional committees serve as a vital conduit to decision makers. EPRI’s research on the technical and scientific bases for policy-relevant issues provides
• comprehensive industry-oriented products, from site case studies to rapid-response technical
interpretation of regulatory proposals;
• groundbreaking integrative research on well-documented health effects, such as cancer occurrence, and
health effects of emerging interest, such as cardiovascular effects from mercury;
• important delineation of source-receptor relationships linking impacts to particular sources and, as
importantly, allowing the exclusion of other sources from consideration; and
• critical reviews and analyses of emerging research findings via technical briefs and integrative
assessment reports.

Accomplishments

EPRI’s Air Toxics program provides distinguished, recognized international expertise in HAPs and multimedia
toxics transport, fate, and health impacts. Scientific results are conveyed to federal and state decision makers
as well as international agencies considering multinational conventions. This research serves as a model for
parallel analyses by others, including government agencies (the original Clean Air Mercury Rule scientific
assessment was based in large part on studies done by EPA that mirrored EPRI research). The program has an
established record of providing research results through open peer-reviewed literature, as well as
communication tools focused on key audiences. In a number of instances, public agencies have sought the
adaptation of published EPRI results as a foundation for technical support documents on mercury and other air
toxics. A key goal of the cooperative research effort is a high multiplier effect: significant use of EPRI resources
through collaboration with and guidance of joint research efforts. These joint projects have been established
with EPA, the U.S. Department of Energy, various state agencies, and the National Science Foundation. Recent
program accomplishments include

• serving as sponsor and key organizer of the United Nations workgroup on mercury fate and transport;
• providing a technical assessment on the health risks of HAPs as part of the current EPA MACT process
for electric generating units;
• briefing U.S. Senate and House of Representative committees on mercury emissions, transport,
deposition, health effects, and time trends;
• developing a dynamic library of communications materials interpreting key results, available to all
stakeholders and communications offices;
• providing the scientific basis for re-examination of the dose-response function for arsenic;
• demonstrating regional mercury changes to state agencies considering alternative regulation; and
• interpreting and critically analyzing influential scientific papers as well as popular press reports of
technical studies.

Current Year Activities

Program R&D for 2012 will focus on rigorous analyses of utility-emitted HAPs risks under emerging operating
conditions, including new and forthcoming regulatory requirements. The continuing evolution of regulation,
legislation, state actions, and public perceptions of risk helps shape the basic and applied studies to be carried
out. Specific efforts will include

• studies of arsenic as an air and multimedia toxic of emerging concern with the increasing stringency of
regulatory health effects levels, including the arsenic cancer slope factor;
• quantification and clarification of the health effects of toxicants at relevant community levels by all
exposure routes;
• studies of trace substance emissions and discharges related to renewable energy resources and future
generation technologies;
• timely delivery to decision makers of thorough scientific information on mercury, arsenic, and other HAPs
during consideration of utility HAPs management;
• better quantification and source attribution of specific contributors to air and multimedia toxics exposure,
domestically and internationally, to inform international negotiations on mercury, arsenic, and other toxics;
- information for and coordination with state agencies on the consideration of mercury and other toxics
- source-receptor issues related to Total Maximum Daily Load (TMDL) regional studies;
- integrative studies of source-to-fate-to-effects pathways for toxicants of relevance; and
- improved methods to quantify environmental trends for mercury and other toxicants following MACT and
other regulations, including clarification of source attribution and exposure.

Estimated 2012 Program Funding

$3.0M

Program Manager

Leonard Levin, 650-855-7929, llevin@epri.com

Summary of Projects

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<th>Project Title</th>
<th>Description</th>
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<tr>
<td>P42.001</td>
<td>Mercury and Multimedia Toxics</td>
<td>This project focuses on mercury and multimedia substance sources, fate, exposure, and health effects. Case studies and modeling of health benefits from proposed regulatory measures are based in this project.</td>
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<tr>
<td>P42.002</td>
<td>Arsenic, Metals, Particulate-Bound Toxics</td>
<td>Arsenic, chromium, and trace metals continue to be a focus of regulation across all environmental media. The impact of multiple utility and nonutility sources, increasing focus on cumulative risk measures, evolving application of toxicological tools, regulatory integration of epidemiological studies, stricter health and media standards, and the potential for wide population exposure require further research focus in this project.</td>
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<tr>
<td>P42.003</td>
<td>Integration and Critical Reviews</td>
<td>Methodologies are developed to create a common approach to vapor-phase trace emissions, their fate, their effects on health and the environment, and human exposure, focused on short-term &quot;upset&quot; conditions and long-term low-exposure effects.</td>
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<tr>
<td>P42.004</td>
<td>Organic HAPs and Acid Gases</td>
<td>A common approach to vapor-phase trace emissions, their fate, their effects on health and environment, and human exposure focuses on short-term &quot;upset&quot; conditions and long-term low-exposure effects.</td>
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<tr>
<td>P42.005</td>
<td>Communications</td>
<td>The program’s widely supported communications effort will continue its emphasis on timely, insightful research summaries, integrative analyses of research, and on-site presentations to both members and external policymakers.</td>
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P42.001 Mercury and Multimedia Toxics (SP3395)

Key Research Question

Even in the transition to a post-MACT regulatory environment in the United States, the role of mercury as an environmental pollutant continues to be a focused research topic nationally and globally. In particular, international transport of mercury is a subject of U.S. negotiations toward a United Nations treaty in 2013. Work continues under federal and state sponsorship on long-range versus local transport and on the potential for state TMDL actions. The complex environmental cycling of mercury, which has similarities to other toxics like arsenic and dioxins, allows an integrated approach to research under a common protocol. Basic science studies of exposure and health effects continue as a result of ongoing efforts seeking lower effects thresholds in infants or other effects endpoints, such as later-in-life onset health effects in adults. Finally, tracking environmental
trends in mercury concentrations in U.S. air, water, and fish is needed because of the follow-on requirements dealing with residual risk. These issues require a comprehensive research approach for evaluating continuing contributors to complex exposures for multiple substances with common endpoints, such as mercury and lead.

**Approach**

This research focuses on basic science studies of mercury and other substances with critical exposure pathways other than inhalation. The project serves as the home for toxics assessments, across all media and all sources, for toxics emitted primarily to the air. The complex environmental pathways involved entail close coordination with several other EPRI programs, particularly in water and in environmental controls. New modeling development work has bridged the gap between global- and local-scale models using whole-atmosphere physical-chemical simulations. The EPRI multimedia model is being used to examine all routes of exposure and effects for current and future generation technologies. Substance-specific case studies with important multimedia routes to exposure are carried out under this project. All of the research results are combined to support integrative studies and trend analyses under project 42.003. Work in 2012 will focus on post-MACT mercury emissions and deposition, incorporating global source trends, for predictive tools on fish recovery and human health outcomes. Case studies will continue for mercury and potential arsenic long-range TMDL studies, while continued monitoring of long-range transport can provide data closure to emissions estimates.

**Impact**

- EPRI’s research and analyses have provided and will continue to produce recognized cutting-edge results that are highly valued by the research community, regulators, policymakers, and the public.
- Program research provides member and cooperating institutions with information to support informed decision making, resource management, and future operations planning.
- The research informs ongoing efforts for long-term national monitoring of mercury trends to evaluate effectiveness of emerging controls and needs for future U.S. regulation.
- Broadening the application of the EPRI family of air and multimedia models allows integration with international modeling studies currently under way.
- As the HAPs MACT rules are implemented, research in this program will be critical to responding to the multitude of follow-up requirements in the regulations.

**How to Apply Results**

EPRI communicates research results to members on an ongoing basis, with continuing updates as research evolves. The primary provision of results in the public domain is via peer-reviewed journals and technical reports. Technical and communications staff members ensure that these results are widely communicated via interpretive EPRI technical briefs and webcasts. Members should be proactive in sending stakeholders the results, ensuring that stakeholders understand those results, and suggesting that results be incorporated into decision making related to improving public health. In addition, EPRI facilitates broader awareness of research results by briefing key stakeholders, including federal and state regulatory and research agencies; developing materials for use by specialty media; keeping EPRI’s public website current; and continuing EPRI staff service on national and international advisory panels.

**2012 Products**

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<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Spatial Gradient of Mercury Dry Deposition from Coast to Inland:</strong> To understand the relative importance of domestic and global emissions of mercury on the input to U.S. ecosystems and the potential for contamination of ecosystems, we must know the variation in concentrations and deposition across space and time. This deliverable investigates mercury deposition and potential sources of mercury to National Parks aligned in a transect across central California into Nevada. This transect stretches from the coastal Point Reyes National Seashore through Yosemite and Sequoia National Parks to</td>
<td>05/31/12</td>
<td>Peer Literature</td>
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Great Basin National Park in southeastern Nevada, and seeks to determine the relative role played by local, regional and global emissions in the observed deposition patterns.

**Using Mercury Isotopes to Identify Source Regions:** The forms of atmospheric mercury include gaseous elemental mercury (GEM), reactive gaseous mercury (RGM), and particulate mercury (Hg-p). It is possible that various anthropogenic sources of GEM, RGM and Hg-p, including coal-fired power plants, emit Hg isotopes in ratios that are significantly different from the natural isotope ratios. It is also probable that redox reactions among these species in the atmosphere will lead to different isotope ratios. This deliverable describes the interpretation of samples of the aforementioned mercury isotope species collected in wet deposition, as a gas, and on particles. It will help determine the environmental variability of isotope ratios and aid in characterizing various anthropogenic emission sources of GEM, RGM and Hg-p by these Hg isotope ratios.

**Laboratory Studies on Conversion of Divalent to Elemental Mercury in Power Plant Plumes:** To better quantify the relationship between anthropogenic sources of atmospheric mercury and deposition at receptors, there is a need to improve our understanding of the sources and chemistry of mercury in the atmosphere. One important component of this source-receptor relationship is the process that causes the reduction of divalent to elemental mercury in coal-fired power plant plumes. This deliverable will identify the primary variables controlling reduction of mercury by heterogeneous reactions involving aged and fresh coal flyash under controlled laboratory conditions, and the development of a semi-quantitative representation of the reduction process that can be used in atmospheric models to represent the chemodynamics in power plant plumes.

**Future Year Products**

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<tr>
<td>High Elevation Measurements of Free Tropospheric Mercury and Halogens in the Tropics</td>
<td>12/31/13</td>
<td>Peer Literature</td>
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**P42.002 Arsenic, Metals, Particulate-Bound Toxics (069557)**

**Key Research Question**

Assessing the potential for community exposure to trace metals and transition metals such as arsenic, chromium, and mercury, as well as delineating any related exposure-to-health relationships, continues to be of critical importance to the electric power industry. As federal agencies consider changes to the technical approaches used in the regulatory risk assessment process, including within EPA, the capacity to provide substantive data to aid in scientifically supported decisions remains crucial. Of particular concern is a focus on providing supporting mechanistic toxicological and analytical exposure data to complement results from human population studies. This integration enables establishment of health criteria grounded in the best available science. The importance of efficiently integrating biological data, particularly on toxicological mechanisms across the environmental dose range, into the regulatory decision process grows as regulatory agencies increasingly rely on data from studies conducted in populations exposed at levels higher than experienced in U.S. community settings. Additionally, engaging across sectors, public and private, in the discussion of the
changing approaches to quantitative risk assessment requires research in a number of areas. These areas include the characterization of uncertainties, alternative default assumptions, changing methodologies for estimating noncancer health risks, and techniques capable of addressing cumulative risk from many stressors. Project results are used to inform decision makers on health risk assessment and to support science-based policy by reducing uncertainties. The goal is to inform the selection of health protective and scientifically supported regulatory measures.

Approach

The focus of this project is to address uncertainties in biological health effects for trace and transition metals. In the absence of detailed scientific information, health assessments rely on conservative default assumptions that are not chemical specific. However, by applying advanced analytical methodology to studying effects on scales from the target cell to the whole organism, key events for deriving the dose-response (D-R) relationships, and ultimately the regulatory health criteria, can be more precisely derived. As in recent EPRI research into the carcinogenicity of arsenic, data integration across disciplines enables the development of a comprehensive biological model capable of accounting for the underlying toxic mode of action. Additionally, this project tracks and evaluates changes in the regulatory risk assessment paradigm, including the application of biomonitoring data, inclusion of nonchemical stressors, and the incorporation of trace metal speciation into regulatory exposure and risk assessments. Another focus of the continuing research is the quantification of pathways involved in toxicological responses to low-dose metal mixtures, particularly those with common modes of action that may relate to the noncancer endpoints observed in epidemiologic studies (such as neurologic or behavioral endpoints) that engender creation of more-conservative health criteria. By first describing the current data for metal-specific effects, and then developing frameworks to integrate these data into health effects values and assessments, EPRI will better inform the emerging regulatory process.

Impact

- Focuses on resolving the basic uncertainties and critical data gaps not addressed by other research. This information is vital to exposure and risk assessments in this and other EPRI programs in water, land, and remediation.
- Provides improved information to assess the quantitative relationship between health endpoints (cancer and noncancer) and individual metals, including chromium, mercury, lead, cadmium, and other metals.
- Reduces uncertainties in key assumptions for health risk assessments, leading to greater accuracy and less reliance on conservative default factors. More-accurate science can lead to reduced costs for compliance measures while still protecting public health.
- Integrates cutting-edge science and technology, such as computational toxicology, genomics, and proteomics, to evaluate health effect results.
- Supports research designed to set reasonable, scientifically supported and health-protective standards through application of the toxicological and epidemiologic data.
- Provides analysis of the changing application of toxicological, biomonitoring, and epidemiologic health data in the regulatory risk process.

How to Apply Results

EPRI communicates health research results to members on an ongoing basis, via continual updates across the scientific community. The primary route of application is via publication in the peer-reviewed literature. The publication of results in the peer literature is prerequisite to its consideration and adaptation by regulatory agencies, particularly at the federal level, such as the EPA Integrated Risk Information System (IRIS) toxicity database. The use of open-literature publications substantiates the relevance of research for application to case studies and its further communication to state agencies. EPRI facilitates broader use and awareness of the results by briefing key stakeholders, including EPA and other federal agencies; developing materials for specialty media; summarizing key results in EPRI technical updates; keeping EPRI's public website current; and continuing EPRI staff service on national and international advisory panels.
## 2012 Products

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<tr>
<td><strong>Summary of the Basis for Changing Chromium Regulatory Health Values:</strong> This technical report will provide a comprehensive review of the status of hexavalent chromium health values (via oral and inhalation routes) for cancer and noncancer effects as established by various regulatory agencies. The report will be useful in informing stakeholders on the scientific basis, changing regulatory evaluation, and potential data gaps for identifying the mode of action for hexavalent chromium at low environmentally relevant levels important for establishing media-specific standards</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>The Influence of Nonthreshold Dose-Response Assumptions for Non-Cancer Health Effects Assessments of Metals:</strong> Recent recommendations by the National Academy of Sciences have refocused the debate on the appropriateness of the traditional regulatory assumption of a threshold, or &quot;no-effect,&quot; level below which noncancer effects will not be seen for environmental toxics. This focus on aligning hazard characterization strategies for all health outcomes indicates a move toward using nonthreshold modeling for estimating dose-response values in regulation of noncancer effects. If carried forward, linear-to-zero modeling for such important contaminants as arsenic and manganese could result in substantial upward revisions in noncancer health values. This deliverable describes the current state and potential effects of applying such default modeling to assessing noncancer dose-response relationships.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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<tr>
<td><strong>Influence of Arsenic Metabolite Exposure in Human Primary Uroepithelial Cells:</strong> As part of the work on arsenic’s biological effects at low doses, the ability to precisely determine the changes in the cellular target of arsenic at the genetic level plays an important role in distinguishing temporary (or adaptive) from more permanent or disease-initiating events. This deliverable details the integration of multiple methods supporting a nonlinear low dose-to-response relationship in a biologically based human risk assessment model.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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<tr>
<td><strong>Arsenic Speciation in Environmental Media: Food:</strong> Arsenic can exist in the environment in several different chemical forms, each with unique toxicological characteristics and a range of exposure potential. This deliverable reviews the state of knowledge of arsenic occurrence and speciation in food and the potential influence of food-based arsenic on multimedia risk assessments.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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## Future Year Products

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<tr>
<td><strong>Noncancer Health Effects of Trace Metals: Status of Regulatory Health Values</strong></td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Integration of Trace Metal Biomonitoring Data into Regulatory Risk Assessment</strong></td>
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<tr>
<td><strong>Arsenic Speciation in Environmental Media: Soil</strong></td>
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<td>Peer Literature</td>
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P42.003 Integration and Critical Reviews (060355)

Key Research Question
This project area is home to the air toxics integrative assessments and critical review efforts—the intensive technical work by EPRI staff and researchers that ties together emissions, fate and transport, basic health effects, exposure, and risk across most or all trace substances of interest. The work covers integrated and multimedia risk assessments, human exposure via all routes and due to multiple chemicals, and industrywide issues. The critical review work in particular focuses on interpreting emerging research by EPRI and others to provide intensive focus on the comprehensiveness, significance, and implications of the findings. It is vitally important to continually initiate, update, and expand these products as research progresses and results are published in the technical literature by EPRI and other researchers. In addition, EPRI has the responsibility to clarify and supplement results and interpretation of results announced by others, which are often issued rapidly and without sufficient insight into the meaning of findings. This work is viewed as “due diligence” by EPRI as part of its mission to inform the public via unbiased, thorough, and wide-ranging research and research interpretation.

Approach
The EPRI staff is closely involved with national and international research review, planning, and interpretation activities through professional societies, national and multinational agencies, and various research steering groups. EPRI staff members serve as reviewers of outside work submitted for publication to technical journals. In addition, EPRI is continually carrying out critical reviews of research issued in both the scientific and popular literature. As research reports are brought to public attention, EPRI prepares both technical and popular research interpretation documents to put these findings in context. An important factor in the development of these products is regularly revisiting emerging issues to revise findings and refine their interpretation. Critical reviews in 2012 will be especially important as exposure and risk interpretations of the 2011 MACT rule emerge and as inter-hemispheric transport issues for substances other than mercury attain new prominence. The first hint of these issues emerged in early 2011 with public concerns over U.S. impacts due to Chinese combustion of imported American Powder River Basin coal.

Impact
- Peer-reviewed publications—research reports issued via peer review in publicly available technical publications, which are the only accepted route for consideration of findings in regulatory and policy reviews.
- Important critical reviews of research results, allowing reasoned, thoughtful input to public debates and response to queries from decision makers.
- Integrative approaches to air toxics from all sources, allowing impacts by source category to be considered in context.
- Credibility and objectivity that allow EPRI to work closely with regulators, policymakers, and the scientific community in sharing research results and conducting joint studies.

How to Apply Results
The integrative studies, by covering the entire range of a risk framework perspective on air and multimedia toxics, as well as critical reviews providing a broad perspective on emerging findings, are the best entry point to the complex technical and policy implications of trace substance issues. Frequent reference to other studies, along with clear reference to EPRI and other focused research, allows multiple audiences to use these studies as the basis for more-focused reports to stakeholders.
### 2012 Products

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<tr>
<td><strong>Post-MACT Inhalation Risk Assessment:</strong> Processing of the 2010 EPA ICR coal and oil utility emissions and fuel data will yield a “present-day” emissions inventory that can be used to focus on inhalation risks following implementation of the 2011 MACT rule. This set of emissions data can then be modified by the MACT limits to yield future-year emissions rates and the consequent deposition and ground-level concentrations representing exposure doses. The resulting risk assessments will provide a direct measure of the risk benefits resulting from the (controls-based) MACT rule, and (more importantly) yield insights into the potential for future regulation: Residual Risk. Key locations and sources likely to be at issue in such post-MACT studies can then be addressed in more detailed analyses and case studies, with significant interaction with members.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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**Urban Air Toxics Screening Assessment:** In addition to residual (post-MACT) risks, EPA is required to address sources of air toxics to (not in) U.S. urban areas. The agency has already stated its intention to include not only the inhalation-route carcinogens mentioned in the Clean Air Act Amendments of 1990, but also noncarcinogens by inhalation and all chemicals by multimedia routes of exposure. EPRI has prepared a Geographic Information System portrayal of locations of power plant sources nationally with respect to EPA-defined urban areas. These urban areas are so broadly defined that much of the western U.S., and a good portion of the eastern U.S., are considered “urban” even in counties with sparse population. The next steps are GIS depictions of pre- and post-MACT airsheds with HAPs concentration exceedances, their contributing sources, and the urban areas underlying those airsheds. The coincidence of higher concentrations with elevated deposition will then provide an entrée into more detailed studies of routes of exposure by all media in those widespread urban areas. | 12/31/12               | Peer Literature     |

**Critical Reviews of Scientific Literature:** A periodic, but intensive, segment of EPRI work is devoted to keeping up with relevant scientific literature in the broad fields involved in the study of hazardous air pollutants. The breadth of knowledge that must be brought to bear on the literature opus is enormous: statistics, environmental fluid dynamics, chemistry, toxicology, etc. Twice yearly, and more often when the occasion calls for it, EPRI staff cull and review the scientific literature for key contributions that may play a central role in our carrying out and interpreting research studies. These reviews are issued to members in June and December and, in addition, rapid critical reviews may be specially issued at any time if emerging literature reports require faster responses. These critical reviews are an important step in promoting the integration of EPRI research across multiple specialties, a key goal of Program 42’s work. | 12/31/12               | Technical Resource   |

### Future Year Products

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<tr>
<td><strong>Urban Air Toxics: Utility-Sensitive Areas</strong></td>
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<td><strong>Air Toxics in School Settings: Contributing Sources</strong></td>
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P42.004 Organic HAPs and Acid Gases (069556)

Key Research Question
Utility emission rates of acid gases such as hydrogen chloride (HCl) and hydrogen fluoride (HF) are typically much greater than those of other trace substances. However, their toxicity levels per unit concentration are significantly less than those of most other HAPS emitted from power plants. The other HAPs emitted in vapor-phase form are primarily organic compounds, ranging from simple substances such as benzene to complex polycyclic aromatic compounds and, potentially, dioxins and furans. Formation and emissions under startup, shutdown, and upset conditions also need to be considered. The vapor-phase form of these substances and their high bioavailability suggest treatment under a common risk-based framework. Their very different sets of exposure pathways and health effects modalities require specific approaches that will depend on the compound(s) analyzed and environmental conditions.

Approach
The key approaches to vapor-phase acid gases and organics require a detailed look at both acute (short-term peak exposure) and chronic (longer-term average exposure) concentration patterns. The specialized tools to quantify such exposures are difficult to assemble and apply, particularly for community exposures. Work in 2012 will be devoted to adapting or developing these specialized approaches for application under a variety of environmental conditions. Among these conditions are short-period operational changes in traditional and advanced fossil power plants; there is evidence of some organics peaking during moderate temperatures during startup, shutdown, and plant cycling. Additionally, even post-MACT acid gas concentrations may reach short-period levels of concern during particular wind and stability conditions. Evaluating these issues requires complex models and simulations that consider short-term, peak-value exposures.

Impact
The focus on risks under both current and future operations requires development of
- better data on organic and vapor-phase emission factors,
- better data on acute health effects (particularly for repeated short-term exposures), and
- flexible modeling tools to evaluate these conditions in addition to chronic exposure.

Increasingly, community responses to power plant operations have involved short-term “upset” conditions, the very conditions often most conducive to secondary organic compound formation within the flue gas stream.

How to Apply Results
The wide range of conditions to be studied dictates a flexible approach to communicating results to members, decision makers, and stakeholders. Evaluation of a number of operating scenarios representative of a typical operating year, with several startup and shutdown transitions per unit, can provide important findings to help bound the risks likely to result from such cycling. The increasing reliance on base unit cycling requires specialized approaches to source terms.
2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Screening Study, Potential for Episodic High-Concentration Acid Gas Events: Over the years, utilities have been approached by members of the public asserting that short-period very high concentrations of acid gases – HCl, HF, etc. – have impacted structures and vehicles close to utility fencelines, causing material and structural damage, potentially harming vegetation, and bringing about secondary or “welfare” impacts. To date, no modeling or monitoring strategy has been able to simulate these events due to time and space resolution of plume models. Techniques are now available to begin either computational (computational fluid dynamics) or experimental (Schlieren photography in wind-tunnel tests) studies of plume downwash at fine spatial and time scales to determine whether these short-term ground-level concentration excursions reach or exceed the order-of-magnitude greater levels assumed in EPA modeling simulations.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Modeling Case Study: Power Plant Excursions of Ground-level Acid Gas Concentrations</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

P42.005 Communications (070640)

Key Research Question

The work on member and external communications of air and multimedia toxics is centered in this project. This very active and worthwhile effort annually issues numerous issue briefs, technical updates, interpretive documents, research announcements, and notices to members and external stakeholders. Much of the communication to members occurs via face-to-face meetings or, increasingly, webcasts. A significant part of the communication project's responsibility is the interpretation of research findings in terms easily accessible to decision makers, regulators, and the public. The proven ability of EPRI program staff to successfully interpret findings in Congressional hearings and other venues will be expanded to other external forums as needed.

Approach

Effective and timely communication of relevant EPRI and external toxics research, and its larger implications, is essential for the results to be considered by both policy and regulatory communities. Communications activities under this project inform the development and interpretation of scientifically sound environmental policy through effective dissemination of significant findings to members, policymakers, regulators, scientists, and the public at large. Results are communicated via

- concise descriptions of key EPRI research findings and their policy implications;
- presentations, briefings, and testimony to key stakeholders, including federal agencies and Congressional panels when invited;
- summary papers on EPRI research and analysis on major issues; and
- frequent timely communication to members via webcast.
Impact

In a number of instances, both members and external decision makers have cited the usefulness of frequent communication with program staff members on current issues. In more than one instance, regulatory and decision-making bodies have relied on EPRI technical reports to prepare their own policy support documents. These communication activities

- inform decision making and support the development of scientifically sound environmental policy;
- help EPRI members stay current on the latest research findings from other groups through technical briefs, critical reviews, and in-person or webcast briefings;
- facilitate informed interaction between EPRI members and decision makers through succinct and timely summaries, targeted presentations, and detailed reports; and
- consider both societal costs and broader benefits entailed in publicly proposed toxics management strategies.

How to Apply Results

Members are urged to participate in and review communications vehicles provided by the program; these represent the best and most frequent portrayal of the key issues that may impact member companies as well as the public. This information is designed to be useful to member corporate communications departments in creating their own tools to address their specific needs. In addition, EPRI facilitates the application of the results through briefings and testimony to key stakeholder groups, regulatory bodies, and federal agencies, as pivotal studies appear or as state or federal processes dictate.

Supplemental Projects

Risk Evaluation of Trace Metals for Air, Water and Solid Waste (072031)

Background, Objectives, and New Learnings

Combustion-related emissions from power plants contain trace metals associated to varying degrees with adverse health effects. As such, the emissions or secondary effects fall under various federal regulations requiring health-based quantitative risk assessment. A primary component of any health-driven risk assessment is a quantitative relationship between the toxicant and the biological response. Numeric estimates derived from such assessments serve as the basis for characterizing risks associated with an exposure scenario. In combination with exposure estimates and other assumptions, agencies use these values to characterize populations at risk, in order to develop media-specific environmental guidelines, standards, permitting, and compliance.

This project will prioritize trace metals undergoing recent or future regulatory review and will develop integrative evaluation and alternative modeling strategies affecting power plants for the development of dose-assessment values as mandated by environmental regulation.

The new learnings will include evaluation of recent changes in EPA health values on combustion-based operations across regulatory programs, integration of toxicological and epidemiologic data for priority trace metals to inform future modeling of health values, and development of models to assess the dose-response relationship for trace metals identified as relevant to power plant operations. Results will be used to estimate the impact of current modeling assumptions based on default and hypothesized health based regulatory values, industry-specific risk assessments, and operational compliance. The project results will also inform industry, regulatory agencies, and the public on risk associated with combustion-based trace metals; promote methodological improvements in modeling; and identify data gaps for future research and operational compliance.
Project Approach and Summary

Research efforts will focus on the following:

- Identify operational and exposure risk to power plants (current or historic sites) due to recent changes in regulatory health values for trace metals (including arsenic and chromium oral cancer values)
- Identify primary health studies for modeling dose-response values for metals under current or future EPA IRIS review, including arsenic noncancer, chromium cancer inhalation, or others
- Evaluate methodological improvements in current regulatory modeling
- Compile available data on exposure estimates for each metal by individual media to improve modeling assumptions
- Identify data gaps to focus specific research areas toward deriving health or exposure data applicable to quantitative risk assessments

Benefits

By relying on general default assumptions that may not integrate chemical-specific data on mode of action, exposure, or other toxicological variables, the resulting regulatory health reference levels can result in regulation on releases across environmental media not derived from all the available science. This project will integrate the available toxicology and health data for metals under current, or future, review by federal agencies. It will provide alternative modeling of available data for establishment of health values, identify data gaps, and make recommendations of studies that provide mechanistic support for improved dose and exposure assessment. Ultimately, the project aims to evaluate health-protective, scientifically supported health values for use in regulatory risk assessment in order to accurately report potential outcomes to the public and industry. In addition, participating companies will have an increased understanding of options and risks associated with combustion-related operations in order to better define research questions and comply with regulations.
Program Overview

Program Description

Implementation of regulatory programs under the Clean Air Act requires the development and application of rigorous air quality models, accurate ambient measurements, and the use of assessment tools based on credible science. Improved techniques are needed for estimating emissions from various sources and for determining the impact of interstate pollution. Previously these tools and techniques have been used to enable informed rulemaking processes for attainment of National Ambient Air Quality Standards (NAAQS), to develop state implementation plans (SIPs), and to make determinations of Prevention of Significant Deterioration during permitting of power plants. However, over the past few years the use of these models has been extended to essentially every part of the air quality regulatory process. In addition to their use in the implementation of standards, air quality models will be applied in the following ways:

- Three-dimensional air quality models, as well as other environmental models, are being used to determine levels of the ambient concentrations of nitrogen oxides (NOx) and sulfur oxides (SOx) to meet a given aquatic acidification standard as part of the Secondary NAAQS for NOx and SOx. This application of these air quality models is unprecedented within the NAAQS process, and thus requires a greater degree of scrutiny on the adequacy of the models.

- With the promulgation of the Primary NAAQS for NO2 and SO2, the U.S. Environmental Protection Agency (EPA) has introduced a new “hybrid” methodology for determining attainment designations of these NAAQS. In addition to deploying monitors to assess whether specific areas exceed the level of the standards, EPA is also requiring major point sources to demonstrate attainment via the use of air dispersion models as part of the designation process. These models have been developed for permitting applications, and as such are quite conservative. The use of models to demonstrate future attainment of standards as part of the SIP process is routine. However, the application of models to define current attainment designations is unprecedented.

- Finally, EPA is continuing to use models to determine the levels of significant contributions to interstate transport of air pollution. As primary and secondary standards for ozone and particulate matter (PM) become more stringent and secondary standards for NOx and SOx are introduced, EPA is expected to continue to develop “Transport Rules” with increasingly smaller thresholds of significance for these pollutants. EPA is likely to continue to use three-dimensional air quality models to establish the upwind/downwind state relations for significant contributions.

Given the already significant use of models and their proposed expansion in the air quality regulatory and management process, it is becoming more important to improve the overall process and thus increase the confidence in their use. This can be accomplished through a three-pronged approach of improving models, emissions inventories, and measurements. It is clear that improving different air quality models (through better representation of chemistry and transport) is essential to informing decisions at different steps of the regulatory process. For the models to provide accurate results, the emissions used as the input to the models should be developed with the best-available science and methods. Finally, only accurate air quality measurements can provide the “ground truthing” to determine if the models are adequate for these proposed uses.

In summary, the electric power industry needs an enhanced understanding of how atmospheric chemical reactions—especially those involving power plant emissions—influence the formation, composition, and health effects of air pollutants. Developing and improving air quality models, improving emissions inventories, and ensuring accurate measurements of air quality, visibility, and deposition are the focus of the Electric Power Research Institute’s (EPRI’s) air quality assessment program.
Research Value

Air quality rulemaking continues to be a key issue for power plant owners and operators. Through this program, EPRI advances the science supporting air quality models used for policy development, regulatory decision making, and implementation planning. Timely communication materials facilitate industry’s ability to respond to questions raised by policymakers, regulators, and other stakeholders. Program research also informs environmental compliance activities, asset management, and long-term strategic planning by power companies. With this research,

- policymakers, regulators and the public will benefit from EPRI’s scientific data, modeling tools, and analytical resources to fully evaluate air quality impacts from all emissions and sources, thereby enabling informed, science-based decision making;
- analysis of additional regulatory options and evaluations of the effectiveness of proposed policies will be performed;
- detailed scientific perspectives on environmental policy and regulatory deliberations of power plant emissions will be provided; and
- collaborations on multimedia environmental issues (such as water quality and ecosystem impacts from atmospheric deposition) and assessment of new technologies (such as electric transportation and distributed energy resources) will increase.

Approach

Research products include air quality models and ambient measurements that clarify how emissions from different sources contribute to the formation of ozone, PM, regional haze, and atmospheric deposition. Additional products include research on atmospheric chemistry and ambient measurement methods essential to allowing health scientists to identify the most harmful air pollution components. These tools are provided to the research and regulatory communities, and their use is encouraged. This program delivers

- independent, objective technical experts who can effectively work with regulatory agencies and the environmental science community;
- the most advanced air quality models, offering the most accurate representation of power plant emissions, chemistry, and transport in the atmosphere;
- multimedia research on the interactions between air quality and climate change, as well as between air quality and watershed management;
- improved techniques for estimating point and nonpoint emission sources; and
- atmospheric measurements that identify air pollution components associated with adverse health impacts, to inform development and application of modeling tools and source-receptor analysis techniques.

Accomplishments

Advanced air quality models and assessment tools based on atmospheric science are critical to informing state and federal air quality management actions in response to more-stringent air pollution standards. This program has

- assessed environmental impacts of plug-in hybrid electric vehicles;
- developed and received regulatory acceptance of a new algorithm for more-realistic accounting of contributions to regional haze;
- evaluated changes in nitrogen deposition due to power plant emissions controls;
- clarified the role of acids in the formation of secondary organic aerosol, and improved representation of the process in air quality models;
- ensured that the Southeastern Atmospheric Research and Characterization (SEARCH) Network continues to yield valuable information for evaluating poorly represented sources, understanding trends, evaluating models, and providing information for health studies;
• implemented an advanced plume-in-grid module to better characterize specific impacts of power plant emissions on ozone, particulate matter, and atmospheric deposition; and
• highlighted the importance of transboundary pollution in regional haze considerations.

Current Year Activities
The program’s R&D for 2012 will continue to focus on the development and application of air quality assessment tools during a significant time in U.S. environmental rulemaking. Key collaborations with EPRI programs on ecosystem/watershed management, energy storage, electric transportation, and coal combustion products management will be crucial in order to inform policymakers, regulators, and other stakeholders. In 2012, program research will

• enhance air quality models and apply those models in regulatory case studies to clarify the contribution of power plants to ozone, PM, haze, and atmospheric deposition;
• evaluate and improve air permitting models;
• conduct additional experiments to enhance understanding of contributions to regional haze from various emission sources;
• continue providing comprehensive information on PM sources, chemistry, and composition essential to understanding air quality health effects;
• improve emissions inventories for highly uncertain categories;
• continue developing improved modules to represent organic PM in air quality models; and
• develop new linkages between air quality and watershed models to assess the contribution of atmospheric deposition from different sources to sensitive ecosystems and waterways.

Estimated 2012 Program Funding
$2.0M

Program Manager
Eladio Knipping, 202-293-6343, eknippin@epri.com
## Summary of Projects

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P91.001</td>
<td>Air Quality Model Development, Evaluation and Application</td>
<td>This project enhances the development and application of comprehensive atmospheric models to better inform air quality policies or implementation plans for compliance with air quality regulations.</td>
</tr>
<tr>
<td>P91.002</td>
<td>Regional Haze Studies</td>
<td>This project provides critical information for improving the implementation of the Regional Haze Rule, focusing on rigorous and realistic assessments of the contributions of various emission sources to visibility degradation.</td>
</tr>
<tr>
<td>P91.003</td>
<td>Improving Emission Inventories</td>
<td>This project will improve the modeling tools, techniques, and emission factor data used to create emission inventories, focusing on ozone and PM precursors from the most uncertain emission sources.</td>
</tr>
<tr>
<td>P91.004</td>
<td>Air Quality Measurements and Analysis</td>
<td>This project will improve the detail, spatial resolution, and temporal resolution of atmospheric measurements and related analyses through small-scale field sampling events or as part of larger collaborative field studies.</td>
</tr>
<tr>
<td>P91.005</td>
<td>Atmospheric Deposition and Ecosystem Impacts</td>
<td>This project will address the major knowledge gaps on sources contributing to atmospheric deposition, as well as the impacts of acid and nutrient deposition to ecosystems.</td>
</tr>
<tr>
<td>P91.006</td>
<td>Air Dispersion Models</td>
<td>This project will evaluate and improve modeling tools used in the permitting of facilities and in attainment demonstrations for the primary SO₂ and NO₂ NAAQS.</td>
</tr>
<tr>
<td>P91.007</td>
<td>Communications</td>
<td>This project will enhance the value of EPRI research by actively communicating results to members and other key stakeholders, particularly federal and state government policymakers and regulators.</td>
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### P91.001 Air Quality Model Development, Evaluation and Application (P21294)

#### Key Research Question

In response to increasingly stringent environmental regulations, there is a continuing need to enhance three-dimensional air quality models in their representation of the atmospheric chemistry and transport of ozone, particulate matter, regional haze, and atmospheric deposition. Traditional research to improve three-dimensional air quality models has focused on their application in the development of state implementation plans (in other words, control strategies) for compliance with air quality regulations. However, over the past few years the use of these models has been extended to essentially every part of the air quality regulatory process. Models are now also being proposed to determine the levels of ambient standards. For example, the air concentrations of NOx and SOx needed to satisfy the level of an aquatic acidification standard developed as part of the Secondary NAAQS for NOx and SOx require the use of several atmospheric and aquatic models due to absence of necessary ambient data for the calculations. This application of air quality models within the NAAQS process is unprecedented, and thus requires a greater degree of scrutiny on model adequacy.

EPA is also continuing to use air quality models to determine the levels of significant contributions to interstate transport of air pollution. As primary and secondary standards for ozone and PM become more stringent, and as secondary standards for NOx and SOx are introduced, “Transport Rules” with increasingly smaller thresholds of significance for these pollutants will likely result. In addition, models will continue to be used to establish the upwind/downwind state relations for significant contributions.
One of the major research needs is to improve representation of organic particulate matter in current air quality models, which continue to lack in that respect. Organic particulate matter can be as prevalent as sulfate particles in urban areas and can contribute significantly to regional particle levels. Pertinent to health-oriented studies, these models also do not simulate ultrafine particles well. There is also a critical need to improve the simulation of near-field emissions in urban landscapes by developing new methods to capture sub-grid-scale impacts, which may dominate air quality at a particular site. Many air quality models still lack an embedded plume-in-grid module, a feature that is needed for accurate simulation of the chemistry and transport of power plant emissions.

Enhanced models developed in this project will provide the best available tools to stakeholders for developing plans in order to attain increasingly stringent ozone and particulate matter standards and meet regional haze goals. For example, these models can be used to assess different control technology and control strategy options.

Approach
This project develops and evaluates computational air quality models. It enhances model capability and reliability for air quality management applications. Advancing the science and thoroughly evaluating the models will increase confidence in their use for environmental policy and regulation development. In addition, this project applies the models to regulatory case studies and helps regulators understand which sources contribute to ozone, PM, regional haze, and atmospheric deposition. Major project activities in 2012 will include

- developing enhanced modules for accurately simulating the different components of PM, especially organic particles, in air quality models;
- enhancing EPRI’s advanced plume-in-grid module in order to better characterize the impact of power plant emissions on ozone, PM, and atmospheric deposition;
- improving modules simulating cloud chemistry and processing of gases and PM;
- using superior air quality modeling systems for simulating the chemistry, transport, and deposition of atmospheric gases and particles in the environment; and
- examining transboundary contributions to ozone, PM, regional haze, and atmospheric deposition in the United States that define policy-relevant “background” levels of these substances.

Impact
- EPRI’s advanced plume-in-grid modules will help electric companies—as well as decision makers and other stakeholders—to better characterize the impact of power plant emissions on ozone and PM formation and atmospheric deposition.
- Advancing the science within these models and evaluating them thoroughly will increase confidence in their use for developing future environmental policies and regulations.
- Planned model applications will help regulators understand the policy-relevant background levels of ozone, PM, regional haze, and atmospheric deposition (the contribution from natural and international emissions to these pollutants and air quality indicators). This information is particularly important in view of more-stringent ozone and PM standards being promulgated by EPA.

How to Apply Results
EPRI members and other stakeholders can apply and use enhancements in air quality models in several ways:
- Air quality models can be used by members or their consultants for applications pertinent to the operation of their facilities.
- Air quality models can be used by federal and state agencies when developing environmental policies and regulations.
- Air quality models can be used by regulatory agencies in development of state implementation plans to meet air quality goals.
- Modules developed by EPRI in other modeling systems can be adopted into air quality models.
EPRI will facilitate regulatory approval of models and their enhancement by working in collaboration with federal regulatory agencies and submitting the model enhancements for formal review and adoption. Members can increase the probability of use of EPRI models by working cooperatively with state regulators and encouraging the use of those models. EPRI will also work with members in developing cooperative projects that enhance application and use of these models. In addition, EPRI staff will facilitate broader use and awareness of the EPRI modeling results by providing timely communication materials, including content available through EPRI’s public website, and through continuing service on various advisory panels.

### 2012 Products

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<th>Product Title &amp; Description</th>
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<tr>
<td>Comparison of Different Configurations of the New Community Multiscale Air Quality Model, Version 5: Different configurations of EPA’s new CMAQ5.0 model will be compared, including model configurations including EPRI-supported modules such as the Advanced Plume Treatment and different modules for organic PM.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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### P91.002 Regional Haze Studies (103321)

#### Key Research Question

EPA’s Regional Haze Rule (RHR) is a long-term regulation that requires visibility in Class I areas to return to natural levels by 2064. In attributing haze to emissions from a specific source, an important step is calculating the relationship between fine particle composition and haze by estimating how much light is scattered or absorbed by sulfate, nitrate, organic materials, black carbon, and other PM components.

EPRI’s research developed a new algorithm, which has been accepted by EPA, for calculating haze indices and attributing haze levels to specific components. Many outstanding issues still remain in understanding the relationship between particle composition and haze, and further research is needed. These issues will be addressed by collection of new particle and visibility data at Class I areas and by focused laboratory studies.

Another key challenge with the RHR is how to define or determine the levels of natural visibility that each Class I area that must achieve by 2064. EPA’s definition of this endpoint does not include transboundary anthropogenic pollutants, as well as new science pertinent to understanding naturally occurring levels of particles contributing to haze. Although EPRI research has demonstrated that states need to recognize the importance of transboundary pollution when developing plans for meeting regional haze progress goals, significant uncertainty remains in estimating the transboundary contribution of organic aerosol concentrations.

#### Approach

EPRI research has played a crucial role in developing a new approach to implementing the RHR and its adoption by EPA. However, many outstanding issues still remain in understanding regional haze impacts from different sources, and further research is needed. This project will address these issues by collection of new particle and visibility data at Class I areas and by focused laboratory studies. The experiments need to be completed by 2012 so that the collective data can inform the regional haze rule implementation methodology. EPRI research on these issues will provide a more rigorous and realistic assessment of the contributions of various emission sources to visibility degradation in Class I areas. Specific tasks in 2012 include:

- completion of analyses of the final advanced experimental study at Acadia National Park, and
- synthesis of all the data from all four experimental studies conducted at various national parks and development of a plan for future analysis.
Impact

- Improves decision making by developing advanced methods for attributing haze to specific sources
- Provides a more rigorous and realistic assessment of contributions from various emission sources to visibility degradation in Class I areas
- Informs state agencies about haze in general—and the contribution of power plants to haze in particular—as the agencies prepare state implementation plans aimed at defining the most cost-effective measures to address local and regional air quality concerns

How to Apply Results

Members are encouraged to communicate project results widely. Members should be proactive in sending results to key stakeholders, making sure that stakeholders understand the results, and suggesting that these results be considered in development of environmental policies, including standards, state implementation policies, and other regulatory decisions. EPRI staff will work with members to these ends. In addition to member efforts, EPRI staff will facilitate broader use and awareness of the results by briefing key stakeholders, including regulatory and other government agencies; developing materials for the trade press/media; keeping EPRI’s public website current; and continuing service on various advisory panels.

2012 Products

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<tr>
<td>Characterization of Visibility Conditions at National Parks: Data collected from a series of experiments conducted at three Class I areas will be analyzed in order to improve the characterization of visibility and the contributions to regional haze from different components of PM.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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P91.003 Improving Emission Inventories (052314)

Key Research Question

Accurate emission inventories are essential to designing sound control strategies to mitigate air pollution. Power plant stack emissions of SO\textsubscript{2} and NO\textsubscript{x} are currently measured with continuous emission monitors (CEMs). However, emissions from many source categories—particularly those associated with on-road and nonroad mobile sources and with agriculture—are estimated using computational emissions models based on limited and often obsolete data. Emissions from other categories, such as local industrial sources, are not regularly monitored or modeled and are often missing from inventories at this time. Power plant stack emissions during plant startup and shutdown periods are currently not characterized; moreover, fugitive emissions from materials piles are estimated using idealized factors in emissions models that may not adequately represent actual conditions. These issues can allow for large uncertainties in emissions estimates used in air quality models, which rely on emissions inventory data as inputs. These uncertainties can in turn lead to incorrect allocation of the relative contributions of various sources to pollutant concentrations in the atmosphere. Since air quality management practices rely on use of the air quality models, these issues can affect permitting, policymaking, and regulatory processes.

In early 2011, EPA released a partial National Emissions Inventory (NEI) for the base year 2008; additional updates are expected throughout the remainder of the year. The 2008 NEI used a new process for collating and performing quality control on the data, which will be under review throughout most of 2011. Careful review of the new inventory is needed to ensure that the best science has been applied to determination of emissions from the various sources and to identify areas where EPRI research may contribute to further improvements.
**Approach**

Current methods for estimating (rather than measuring) emissions can impact air quality assessments based on emissions inventory data, and thus dramatically affect subsequent policymaking and regulatory processes. This project will improve the modeling tools and other techniques used to create emission inventories, as well as the emission factor data used as inputs to these calculations. Emissions of ozone precursors (volatile organics and nitrogen oxides) as well as PM precursors (such as sulfate, nitrate, and ammonia) are of interest. The focus will be on sources or processes with the most uncertain or limited amount of available emissions data; research could include both modeling and measurement studies. In 2012, improvements to on-road and nonroad mobile emission source models will continue, with a focus on organic carbon. Investigations of sources of nitrogen-containing chemicals (such as ammonia) through improved measurement techniques or inverse modeling studies in 2012 will help clarify PM concentrations and transformations.

**Impact**

- Expands knowledge of emissions sources of uncertain magnitude that contribute to ozone and PM levels
- Investigates options for potential emissions offsets for electric utilities resulting from vehicle/engine replacement or other actions
- Improves decision making by helping to determine the extent to which different sources are contributing to air pollution, enabling electric utilities, other industries, regulators, policymakers, and other stakeholders to determine the most efficient, cost-effective measures for addressing local and regional air quality concerns

**How to Apply Results**

Members are encouraged to communicate project results widely. Members should be proactive in sending results to key stakeholders, making sure that stakeholders understand the results, and suggesting that these results be considered in development of environmental policies, state implementation plans, and other regulatory decisions. EPRI staff will work with members to these ends. In addition to member efforts, EPRI staff will facilitate broader use and awareness of the results by briefing key stakeholders, including regulatory and other government agencies; developing materials for the trade press/media; keeping EPRI’s public website current; and continuing service on various advisory panels.

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<tr>
<td>Updated Emissions Estimates for Use in Inventories: Updated measurements and modeling approaches are used to better estimate direct or fugitive emissions from sources.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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**P91.004 Air Quality Measurements and Analysis (069212)**

**Key Research Question**

Improving the detail and resolution of atmospheric measurements is essential for understanding the various transformation processes of emissions in the atmosphere and best representing those processes in atmospheric models. It is also crucial for studying the human health and ecosystem effects of air pollution. High quality, highly time-resolved measurements are required for evaluation of three-dimensional air quality modeling tools.
Such measurements also provide the necessary input to source-receptor models, which are used in weight-of-evidence analyses to determine sources contributing to pollution at a receptor site. However, most modeling studies rely only on ambient measurements from national monitoring networks, which for PM and its constituents are often taken only as 24-hour average or cumulative measurements. These measurements can obscure or miss rapid changes in atmospheric composition and processing. In addition, these networks typically use instruments designed first and foremost to be easy to operate and maintain, and many of these instruments are becoming increasingly outdated. Often, these methods may not provide the highest quality data in terms of chemical specificity, detection limits, or number of chemicals measured. Finally, static networks cannot cover all spatial and temporal locations of interest. Lack of high-resolution measurement data implies that air quality models are not subject to rigorous evaluation, and use of those models can result in misinterpretation of model results, with subsequent impacts to air quality management strategies.

Approach

EPRI research on atmospheric measurements, their interpretation, and relevant instrumentation has played a key role in conducting health studies, developing and validating air quality modeling tools, and determining applicability of source attribution and receptor modeling analyses. This project will continue to improve the detail and the spatial and temporal resolution of atmospheric measurements through both planned projects and projects of opportunity. In 2012, this work will include a small-scale field sampling event coordinated with university researchers to investigate effects of biogenic and anthropogenic emissions on air quality and to improve air quality chemical models. This study will supplement and leverage the work performed at the heavily instrumented SEARCH network sites. In addition, EPRI will participate in organizing a large-scale field study in 2013 in collaboration with government agencies and research institutions. This work will complement and extend the existing suite of atmospheric measurements, allow for critical evaluation of measurement techniques and data analysis/interpretation, allow flexibility to address unanticipated questions by nature of the collaborative efforts, and take advantage of large multiresearcher datasets.

Impact

- Improves the detail and resolution of atmospheric measurements, enabling health researchers to determine how the various components of air pollution contribute to observed health effects in the environment and informing the development and application of air quality modeling tools and source-receptor analysis techniques
- Provides comprehensive data from state-of-the-art measurement techniques to complement or improve upon those that are available in current national monitoring networks and databases and that are used for determining air quality and management strategies
- Enhances knowledge about the various sources contributing to air pollution, enabling electric utilities, other industries, regulators, policymakers, and other stakeholders to determine the most efficient, cost-effective measures to address local and regional air quality concerns

How to Apply Results

Members are encouraged to communicate project results widely. Members should be proactive in sending results to key stakeholders, making sure that stakeholders understand the results, and suggesting that these results be considered in development of environmental policies, including standards, state implementation plans, and other regulatory decisions. EPRI staff will work with members to these ends. In addition to member efforts, EPRI staff will facilitate broader use and awareness of the results by briefing key stakeholders, including regulatory and other government agencies; developing materials for the trade press/media; keeping EPRI’s public website current; and continuing service on various advisory panels.
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<tr>
<td><strong>Ambient Measurements of Power Plant Plume Impacts:</strong> Measurements collected under different atmospheric conditions, including conditions representative of influences by power plant plumes, will be compared to determine to what extent power plant plumes may affect the amount and composition of particulate matter in the atmosphere.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
</tr>
</tbody>
</table>

Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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</thead>
<tbody>
<tr>
<td><strong>Ambient Measurements of Particulate Matter Composition:</strong> Ambient measurements using state-of-the-art instrumentation will be analyzed to determine how different components of particulate matter vary in the atmosphere.</td>
<td>12/31/13</td>
<td>Peer Literature</td>
</tr>
</tbody>
</table>

P91.005 Atmospheric Deposition and Ecosystem Impacts (069213)

Key Research Question

Atmospheric deposition of acids and nutrients can influence the biogeochemistry of ecosystems. Deposition of several atmospheric pollutants can lead to acidification, which has been associated with a decline in forest tree species and loss of biodiversity in aquatic ecosystems. Nutrient deposition has been associated with disruption in the biodiversity of ecosystems and eutrophication of water bodies, which can contribute to toxic algal blooms and fish hypoxia.

In the past several years, there has been increasing focus by the regulatory and scientific communities on atmospheric deposition as it relates to acid and nutrient loading in ecosystems. EPA is considering proposing a new Secondary NAAQS based on an aquatic acidification standard. EPA has also indicated that it will continue to explore how other ecological impacts (terrestrial acidification and aquatic/terrestrial nutrient enrichment) may also be incorporated into future Secondary NAAQS for SOx and NOx. In addition, EPA has assembled an Integrated Nitrogen Committee under its Scientific Advisory Board to assess the fate and impacts of reactive nitrogen species throughout different environmental media.

Despite the renewed interest in these ecological impacts, the tools used to evaluate atmospheric deposition are inadequate to inform current decisions and policies. The policies and standards being proposed rely on the concept of critical loads as a means to protect sensitive ecosystems from the impact of atmospheric deposition. However, the critical load methodologies are overly simplistic, and the ecological indicators employed may not accurately represent the true state of ecosystem health.

Approach

This project will conduct a detailed review and analysis of different methods for assessing the impact of deposition on the various terrestrial indicators. In addition, this research is being complemented with a supplemental project on acidification and nutrient enrichment to address two key issues: reliance on overly simplistic aquatic models, and reliance on wet deposition networks with no consideration for dry deposition. The latter topic is of particular concern since EPA is pursuing the use of models, with various adjustments and “bias corrections,” to determine depositional loads without a means to determine the adequacy of the models to represent deposition.
This project will address the major gaps in the understanding of the sources contributing to atmospheric deposition, as well as the impacts of acid and nutrient deposition to ecosystems, by carrying out a suite of focused projects over several years. In 2012, one or both of the following projects will be undertaken depending on priorities:

- A critical review and evaluation of different methods used to address atmospheric deposition to sensitive ecosystems, such as critical loads, regional TMDLs, and secondary NAAQS standards for SOx and NOx
- Continued enhancement of the linkage between air quality and watershed models, thereby providing a dynamic tool to inform policymakers and support exploration of emerging issues, such as the inclusion of atmospheric deposition reduction credits in water quality trading schemes

**Impact**

- Improves decision making by determining the extent to which different sources are contributing to atmospheric deposition
- Enhances the linkages between air quality and watershed models, thereby enabling informed environmental policy
- Conducts analysis of the best methods for regulators and policymakers to address atmospheric deposition concerns

**How to Apply Results**

Members are encouraged to communicate project results widely. Members should be proactive in sending results to key stakeholders, making sure that stakeholders understand the results, and suggesting that these results be considered in development of environmental policies, state implementation plans, and other regulatory decisions. EPRI staff will work with members to these ends. In addition to member efforts, EPRI staff will facilitate broader use and awareness of the results by briefing key stakeholders, including regulatory and other government agencies; developing materials for the trade press/media; keeping EPRI’s public website current; and continuing service on various advisory panels.

**2012 Products**

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<tr>
<td><strong>Assessment of Deposition Impacts on Aquatic and Terrestrial Ecosystems:</strong> National water quality and soil data will be used to assess the extent to which atmospheric deposition of different components from various sources contributes to aquatic and terrestrial acidification in key regions of the United States.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
</tr>
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</table>

**P91.006 Air Dispersion Models (070641)**

**Key Research Question**

The permitting process for power plants and other large industrial sources relies heavily on the application of air dispersion models. These are used to determine compliance with NAAQS and other regulatory requirements such as New Source Review (NSR) and Prevention of Significant Deterioration. In its Guideline on Air Quality Models, which was designed to provide consistency and equity in the use of modeling within the U.S. air quality management system, EPA has identified two preferred (recommended) “guideline” models: AERMOD, a steady-state plume dispersion model for near-source applications, and CALPUFF, a non-steady-state puff dispersion model for long-range transport applications.

EPA has recently promulgated new one-hour sulfur dioxide (SO₂) and nitrogen dioxide (NO₂) standards with a requirement that models be used to determine attainment compliance. As a result, the adequacy of EPA’s guidelines and accuracy of its preferred models are paramount. The AERMOD model has been shown in...
several scientific forums to be too conservative for NO\textsubscript{2} due to simple assumptions on NO-to-NO\textsubscript{2} conversion rates. Furthermore, the modeling methodology required by EPA uses peak emission rates throughout a full annual simulation, resulting in unrealistically overestimated emissions for all pollutants, which will impact compliance with short-term ambient standards. Similarly, for long-range applications, the CALPUFF model is also considered too conservative in its estimates of PM formation from SO\textsubscript{2} and NO\textsubscript{2}.

The process and modeling tools used for the NSR program and visibility analyses in the Regional Haze Rule may give overly conservative estimates of a source’s potential contribution to ambient pollutant concentrations and visibility impairment because of inherent assumptions built into these tools. There is a need to determine if either could be improved. Recent advances in computational speed suggest there may no longer be a need to restrict these analyses to the simplest form. Developments in three-dimensional atmospheric models could be transferred to improve air dispersion models or to create hybrid modeling systems.

**Approach**

This project will improve existing models to remove or minimize potential biases and explore whether better alternatives to existing models can be supported. Evaluations will be performed by comparing the newly developed methodology and models with their original counterparts. This will be accomplished by testing new methodologies for air dispersion model applications for the new short-term standards, improving existing dispersion models for both near-source and long-term application, and evaluating the adequacy of an alternate model within the EPA Guideline process.

**Impact**

- Improves the air permitting process and attainment demonstration process by developing better tools for determining contribution of a single industrial source to air quality
- Ensures a higher degree of confidence in use of dispersion models

**How to Apply Results**

EPRI members and other stakeholders can apply and use enhancements in air dispersion models in several ways:

- The improved air dispersion models can be used by members or their consultants for permit applications related to new construction or modifications in their facilities.
- The improved air dispersion models can be used by members or their consultants to determine compliance with primary SO\textsubscript{2} and NO\textsubscript{2} standards.
- The improvements in the models as a result of EPRI research can be adopted by EPA and other regulatory bodies.

EPRI will facilitate regulatory approval of the enhancement of the air permitting models by working in collaboration with federal regulatory agencies and submitting the model enhancements for formal review and adoption. Members can increase the probability of use of the enhanced models by working cooperatively with state regulators and encouraging the use of those models. EPRI will also work with members in developing cooperative projects that enhance application and use of these models. In addition, EPRI staff will facilitate broader use and awareness of these models by providing timely communication materials, including content available through EPRI’s public website, and through continuing service on various advisory panels.

**2012 Products**

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<tr>
<td><strong>Application of Improved Air Dispersion Models:</strong> An evaluation of EPA’s guideline models for air quality modeling (air dispersion modeling) will be performed to determine how different approaches, configurations, and improvements to science modules can improve their use for regulatory purposes.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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P91.007 Communications (060356)

Key Research Question

EPRI research on various air quality issues will have enhanced value to members and society if the results are actively communicated to and applied by key stakeholders, particularly federal and state government policymakers and regulators. EPRI's reputation for credible research results and its standing in the scientific community provide opportunities for informing key stakeholders of the latest scientific findings on air quality issues. EPRI members have recognized the critical nature of the communication materials provided to date and continue to underscore the importance of continuously updating these materials as new information becomes available.

Approach

Effective communication of EPRI research on air quality issues is essential for the results to be considered and applied by the policymaking and regulatory communities. Communications activities under this project inform decision making and support the development of scientifically sound environmental policy through effective dissemination of significant research results to EPRI members, policymakers, regulators, scientists, and the public at large.

These results are communicated via

- succinct descriptions of key EPRI research findings and their implications on a timely basis;
- presentations, briefings, and testimony to key stakeholders;
- detailed summary papers on EPRI research and analysis on major issues; and
- critical reviews of external studies published in technical reports or technical papers.

Impact

- Informs decision making and supports the development of scientifically sound environmental policy through effective dissemination of significant research results to EPRI members, policymakers, regulators, scientists, and the public at large
- Helps EPRI members stay current on the latest research findings from other groups through reviews of external studies (technical reports and scientific papers)
- Facilitates informed interaction between EPRI members and decision makers through succinct communications materials, targeted presentations, and detailed reports on a timely basis
- Ensures that costly air quality regulations are based on sound science and that investments in technology to reduce emissions provide maximum societal value

How to Apply Results

Members should review the communications materials for information that is relevant to their stakeholders, policymakers, and regulators. This information is useful to member company corporate communications departments and to local, state, and federal liaisons in creating messages and plans to proactively communicate the research findings to appropriate stakeholder groups. In addition, EPRI facilitates application of the results through briefings and testimony to key stakeholders, including state and federal government agencies, as pivotal studies appear or as state or federal actions dictate.

2012 Products

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<tr>
<td>Communication Products: This program releases a variety of products to help members communicate on a range of issues related to air quality modeling, contributions from different sources to pollutant levels, regional haze, emissions, ambient measurements, atmospheric deposition, and air dispersion models. These products consist of webcasts, issue briefs, critical reviews, and presentations to key stakeholders.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
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</table>
Acidification and Nutrient Enrichment (072064)

Background, Objectives, and New Learnings

Over the past several years, EPA has taken steps to propose a combined Secondary NAAQS for NOx and SOx. A proposed rule is expected in July 2011, with potential promulgation in early 2012. This proposal would be the first time that EPA addresses multiple criteria pollutants under one standard, and also the first time it uses air standards to address a concern in other environmental media (water and soils) due to the linkage through atmospheric deposition. EPA has developed a complex technical methodology to link atmospheric concentrations of SOx and NOx to atmospheric deposition in support of this unprecedented multipollutant, multimedia standard. This methodology relies heavily on the use of models to provide values for important parameters for which no data exist and no model evaluation can be performed. In addition, there are numerous simplified assumptions used in the proposed methodology without adequate validation that may show problems with the methodology itself.

The most critical aspect of the proposed methodology is the application of three-dimensional air quality models, as well as aquatic models, to develop linkages from ambient concentrations of NOx and SOx to atmospheric deposition and then ultimately to aquatic acidification, as part of the Secondary NAAQS for NOx and SOx. These models have not been evaluated adequately, and EPRI analysis has shown overlay conservative biases in the parameters of aquatic models and in their application. The approach proposed by EPA evaluates spatial variability in the air quality and aquatic data which could potential result in an overly conservative bias in the standard. Additionally, it is unprecedented that model simulations, rather than measured data, are being used to determine the level of the standards within the NAAQS process. Of the several reasons given by EPA for using models, the principal rationale is the lack of measurements of dry deposition fluxes of all atmospheric constituents. Since use of the models is being proposed for development of the standard (rather than only for implementation, when the models would be used in a relative sense), a greater degree of scrutiny of their adequacy is required.

By understanding the rationale for EPA’s methodology for the secondary SOx and NOx standards, there are many research issues that need to be addressed. There is aneed is for direct measurement of deposition rates and ambient concentrations, so that a linkage between deposition and concentrations can be evaluated and tested with empirical evidence rather than through the use of the models. If the deposition measurements can be made relatively inexpensively over a wide network, researchers could begin to explore whether a standard based on measurements alone could be supported. In the short term, these measurements can also provide the “ground truthing” to determine if the models are adequate for these proposed uses. Without this information, models will continue to be used without testing and evaluation of their ability to represent the flux of pollutants to ecosystems. Availability of measurements also would allow researchers to better understand any biases in EPA’s methodology and to develop means to reduce those biases.

Project Approach and Summary

The research in this supplemental project focuses on the following key topics:

- the development of inexpensive dry deposition measurements to test conceptual assumptions of the relationship between deposition and ambient concentrations, and to evaluate the ability of air quality models to accurately represent total depositional fluxes to ecosystems
- the collection of data in various aquatic systems in the United States to more accurately validate the aquatic models and terrestrial relationships
- the improvement of simple and complex aquatic models to represent the actual dynamic response of ecosystems to varying composition, meteorology, and other natural and anthropogenic environmental stressors
The work in this supplemental project complements the efforts within the Annual Research Portfolio on air quality model development (91.001), ambient air quality measurements (91.004), and source attribution of deposition via air quality models, linkages of air quality and water quality models, and atmospheric deposition policy analysis (91.005). The additional tasks of this supplemental project can also be extended to address other environmental issues related to atmospheric deposition, such as the determination of regional total maximum daily loads (TMDLs), inclusion of air deposition credits in water quality trading programs, vegetation impacts, and overall environmental sustainability.

Benefits

It is important to understand the impacts of secondary standards. State implementations plans for secondary standards do not have fixed timelines; states are expected to reach attainment “as expeditiously as practicable.” However, designation of nonattainment of secondary standards results in the same restrictions on new sources and modified sources as does nonattainment of primary standards: the sources must undergo the New Source Review process. Given the large extent of the potential nonattainment areas, such restrictions could severely affect the construction of new power plants or the cost-effectiveness of modifications to existing units over large regions of the United States. The public will potentially benefit by gaining a better understanding of how costs and timelines of any power plant modifications may affect electricity costs in the future. In addition, EPA could also enact a “Transport Rule” in order to limit the amount of interstate contributions to secondary SOx and NOx exceedances which may also affect costs of new or existing units. The public will benefit by understanding any potential variances which may impact rate payor increases or timelines for new construction of plants.

Results of the proposed research are expected to affect the implementation of any final proposed standard based on the current methodology being used by EPA, as the research will result in better data to ground-truth assumptions and parameter values as well as to test the adequacy of the models employed. Furthermore, this research will inform the next phase of scientific review of the NAAQS (as part of EPA’s five-year NAAQS review cycle) with availability of relatively inexpensive ways to measure dry deposition and a rich data set that can be used to evaluate and test current and future proposed methodologies related to the different environmental endpoints of concern.
Assessment of Air Quality Impacts on Human Health - Program 92

Program Overview

Program Description
Protecting public health and the environment is the primary goal of environmental regulation. However, how to achieve that goal is an ongoing dialogue among regulators, administrators, scientists, and others. The Clean Air Act’s National Ambient Air Quality Standards (NAAQS) have set limits for ambient concentrations of six “criteria” pollutants (carbon monoxide [CO], lead, nitrogen dioxide [NO2], particulate matter [PM], ozone [O3], and sulfur dioxide [SO2]) considered harmful to public health and the environment. Recognizing that knowledge about health and environmental impacts of air pollutants evolves as scientific studies produce new results, the Clean Air Act requires periodic review of the standards and of the science upon which the standards are based. The science generated under this program informs this standard-setting process as well as other regulatory actions at the local and national level. Conducting research that informs this review process is the focus of the Electric Power Research Institute’s (EPRI’s) Air Quality Health program.

This program delivers information on the health impacts of air pollution to help members, regulators, and other stakeholders develop scientifically sound policies and standards for achieving acceptable air quality to protect public health. The program’s health effects information, developed from epidemiology, toxicology, and exposure assessment studies, addresses key scientific uncertainties related to health effects of PM, ozone, and other air pollutants. The focus of current research is on determining which components of air pollution—in particular, which components of fine particles—are most closely associated with negative health impacts.

Research Value
EPRI’s Air Quality Health program has the potential to catalyze a paradigm shift in how air pollution, specifically PM, is regulated in the United States and perhaps internationally. The current regulatory approach is mass based, regulating the total PM concentration. However, PM is composed of hundreds of individual components, and there is a growing consensus that not all of these components are equally toxic. EPRI’s air quality health research addresses key scientific uncertainties to determine which components of air pollution are associated with negative health impacts (and which are not) and generates information to support health risk estimates of air pollution components. The value of the research is in its ability to identify the true causative agents, and the sources of those agents, affecting human health and the environment. With this program

- air pollution health research considers the full spectrum of pollutants necessary to ensure that public health is adequately protected; further, EPRI is the only R&D organization that understands unique electricity sector issues and how they fit into the larger picture of emissions from other sources; and
- peer-reviewed publications on the health effects of specific PM sources and components provide input into regulatory standard-setting processes and inform the broader stakeholder community.

Approach
EPRI air quality health research is critical to the U.S. Environmental Protection Agency's (EPA's) statute-required review of air pollution standards and will be considered in the revision to the NAAQS for PM expected in 2016. EPRI also provides briefings to state and federal policymakers on its research results. EPRI takes the unique and multidisciplinary approach of combining epidemiology, toxicology, and exposure assessment studies organized into a new issue-based framework focusing on PM and its components, NO2, SO2, ozone, and fly ash resuspended from landfills or plant operations. The issue areas will use the following study designs/disciplines to achieve the required results:

- Air pollution epidemiology studies examine human populations to determine the statistical links between pollutant exposures and adverse health effects.
- Exposure assessment studies characterize the components and sources of air pollution to which people are exposed.
Toxicology studies are laboratory studies conducted in cell systems, animals, or humans that evaluate health impacts of pollutants under controlled conditions.

Integration and synthesis of epidemiology, toxicology, and exposure studies allow consistency of results across these three disciplines to enable development of more-robust health effects information. Finally, the program’s communication activities ensure that results are disseminated to stakeholders, including the public, in an easily understandable and usable form.

Accomplishments

EPRI’s Air Quality Health program focuses on providing better understanding of the roles played by PM components and other air pollutants. Major accomplishments include:

- Epidemiology studies, such as the landmark Aerosol Research and Inhalation Epidemiology Study (ARIES), have significantly advanced knowledge of air pollution health effects, especially the differing potencies of PM components.
- Cohort studies, such as the Veterans Study, indicate the importance of traffic and organic compounds as predictors of premature mortality.
- The Toxicological Evaluation of Realistic Emissions of Source Aerosols Study, examining the health effects of coal-fired power plant emissions, has shown subtle effects in laboratory animals, which are generally milder than responses to concentrated ambient particles.
- The Bi City Concentrated Ambient Particle Study shows adverse cardiovascular effects to be linked primarily with trace metals from smelting, incineration, and metal processing sources.
- EPA’s Clean Air Scientific Advisory Committee recognized the importance of PM components and identified this as an issue for EPA’s upcoming reviews of the ambient-standard–setting process.

Current Year Activities

Program R&D for 2012 will focus on continuing to evaluate the relationships between air pollution and health, with emphasis on understanding the role played by specific PM sources and components. Specific efforts will include:

- epidemiological studies to better determine the sources and components of air pollution responsible for health effects; ongoing work will include ARIES studies in Atlanta, St. Louis, Dallas, Birmingham, and Pittsburgh, and the Children’s Air Pollution Asthma Study in New York City;
- toxicological studies to provide additional information on the role played by different air pollutants in adverse health effects; studies will include the Michigan Integrated Cohort and Animal Particle Study;
- exposure assessment studies to evaluate the means by which people are exposed to air pollution; research will include evaluation of particle- and gas-phase exposures in microenvironments (for example, homes) as well as personal exposures;
- an assessment of the role played by carbon—a significant contributor to particle mass and also present in gaseous form—in adverse health effects, in conjunction with ongoing studies and analyses;
- a literature review on the health effects of coal combustion products;
- integration of studies in epidemiology, toxicology, and exposure assessment through evaluation of research by EPRI and others, to arrive at robust conclusions regarding health impacts of air pollution; and
- targeted communications for members and other stakeholders, including white papers, reviews, issue briefs, webcasts, and briefings.

Estimated 2012 Program Funding

$2.2M

Program Manager

Annette Rohr, 650-855-2297, arohr@epri.com
### Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P92.001</td>
<td>Particulate Matter (PM) and Components</td>
<td>This project focuses on developing scientifically robust and sound information about the health effects of PM and its components using both epidemiological and toxicological approaches.</td>
</tr>
<tr>
<td>P92.002</td>
<td>Sulfur and Nitrogen Dioxides</td>
<td>This project will investigate the health effects of sulfur and nitrogen oxides (SOx and NOx).</td>
</tr>
<tr>
<td>P92.003</td>
<td>Health Effects of Coal Combustion Products</td>
<td>This project will evaluate the potential health impacts from exposure to coal ash through the completion of a detailed literature review summarizing known risks and outlining any research deemed necessary.</td>
</tr>
<tr>
<td>P92.004</td>
<td>Integration and Synthesis</td>
<td>This project provides integrated information on air pollution and health that can be disseminated to stakeholders, including regulatory and other government agencies.</td>
</tr>
<tr>
<td>P92.005</td>
<td>Communications</td>
<td>This project provides access to a wide variety of communications tools related to air quality and health issues.</td>
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</table>

### P92.001 Particulate Matter (PM) and Components (069215)

#### Key Research Question

The NAAQS for PM are reviewed on a five-year cycle. The current standard is often exceeded in many parts of the country, and secondary particles associated with utility emissions (sulfates and nitrates) are a major component of ambient PM. One of the most pressing needs regarding the regulation of PM is a better understanding of the PM sources and components most strongly associated with observed adverse health impacts. High quality, scientifically robust, and focused epidemiological and toxicological studies are needed to inform regulators and other stakeholders about the differential toxicity of PM components in ensuing rounds of the NAAQS review. Health studies are the basis for ensuing regulatory responses by states, and it is critical that these agencies understand which sources may or may not be contributing to observed health effects while meeting mandated standards and developing state implementation plans (SIPs).

#### Approach

This project consists of specific studies aimed at increasing knowledge of the health impacts of PM sources and components. Epidemiology studies, following the ARIES model in Atlanta, are being carried out in several cities, including St. Louis, Dallas, Pittsburgh, and Birmingham. Studies will evaluate mortality and morbidity endpoints (both cardiovascular and respiratory) when considering the effects of air pollution on human health. Advanced statistical techniques will be employed to determine the associations between specific PM components and various health endpoints and to integrate results across geographic areas. The Children's Air Pollution Asthma Study is another study under the ARIES umbrella. This study is determining the relationship between specific air pollutants—as well as exposure to traffic—and asthma in children. Exposure assessment studies will be performed to increase knowledge of the primary sources of PM exposure in specific populations. Finally, toxicology studies will be carried out that focus on the contribution of individual PM sources and components to adverse health effects in laboratory animals. These studies include the Michigan Integrated Cohort and Animal Particle Study (MICAPS). In 2012, additional findings from the ARIES suite of studies will be published, along with results from MICAPS. Meta-analyses that combine the results across cities will be initiated. Analyses will also be extended to consideration of organic components.
Impact

- Provides key information to be considered by EPA in the next review of the fine particulate matter (PM$_{2.5}$) NAAQS.
- Provides credible science to assist in the development of SIPs and other air quality regulatory activities.
- Supports research designed to better protect public health.
- Provides cost-effective emissions reduction analyses. Identifying differences in PM component toxicity could have a significant impact on the costs to implement potential future emissions reductions.
- Provides a realistic estimate of the health impacts of coal generation.
- Aids members in their communication efforts with regulators and customers.

How to Apply Results

Members are encouraged to communicate project results widely. Members should be proactive in sharing the results with stakeholders, ensuring that stakeholders understand the results, and suggesting that results be considered in environmental policymaking (including standards, SIPs, and other regulatory decisions). EPRI staff will work with members to these ends. In addition to member efforts, EPRI researchers will facilitate broader use and awareness of the results by briefing key stakeholders, including regulatory and other government agencies; developing materials for the trade press/media; keeping EPRI’s public website current; and continuing service on various advisory panels. Peer-reviewed scientific papers will be prepared by EPRI staff and contractors to ensure that the results meet the highest scientific standards. These papers will be made available to key stakeholders, including the public.

2012 Products

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<tr>
<td>Epidemiological Studies of PM Components and Health:</td>
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<tr>
<td>This peer literature product will present results of epidemiological studies designed to investigate associations between PM components and health effects.</td>
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<tr>
<td>Toxicological Studies of PM Components and Health:</td>
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<td>This peer literature product will present results of toxicological studies designed to investigate associations between PM components and health effects.</td>
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P92.002 Sulfur and Nitrogen Dioxides (069216)

Key Research Question

Air pollution is a complex mixture composed of multiple particle- and gas-phase materials. The criteria gases, which are regulated by EPA under the NAAQS, include SO2, NO2, CO, and ozone. The roles played by NO2 and SO2 in health effects attributed to air pollution need to be clarified in order to most effectively protect public health, particularly in light of recent rulemaking activities that have proposed changes to the current NAAQS for these two gases.

Approach

This project will examine, using a multidisciplinary approach of epidemiology and controlled human exposures, the health effects of criteria gases. In epidemiology studies like the ARIES suite, associations between criteria gases and mortality/morbidity endpoints will be examined individually (in single-pollutant models) as well as jointly with other pollutants (in multipollutant models). Work in 2012 will include publication of ARIES results related to SO2 and nitrogen oxides (NOx), as well as meta-analyses focused on these pollutants.

Impact

- Project research supports better protection of public health by using sound science to evaluate the health effects of SO2 and NOx.
- Project results will be considered by EPA in the review of the NAAQS.
- Research results will be used by state regulatory agencies in the development of state implementation plans.

How to Apply Results

Members are encouraged to communicate project results widely. Members should be proactive in sharing the results with key stakeholders, ensuring that they understand the results, and suggesting that results be considered as part of environmental policymaking (including standards, state implementation plans, and other regulatory decisions). EPRI staff will work with members to these ends. In addition to member efforts, EPRI researchers will facilitate broader use and awareness of the results by briefing key stakeholders, including regulatory and other government agencies; developing materials for the trade press/media; keeping EPRI’s public website current; continuing service on various advisory panels; and holding workshops.

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<tr>
<td>Health Studies of SOx and NOx: This peer literature deliverable will describe the results of epidemiology studies, controlled human exposure studies, or both investigating the health effects of SOx and NOx.</td>
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P92.003 Health Effects of Coal Combustion Products (070643)

Key Research Question
Coal combustion products (CCPs) are composed of fly ash, bottom ash, boiler slag, and solids generated from flue gas desulfurization (FGD) systems. These materials are often stored in large impoundments in either wet or dry form. Although there has been extensive toxicological research on coal fly ash—driven primarily by its contribution (albeit very low) to ambient particulate matter via stack emissions—the potential health significance of the stored products has not received significant attention to date. A better understanding of the possible health impacts of windblown CCPs would inform decision making related to protection of public health; such knowledge could also be extended to workplace environments where occupational exposures may occur.

Approach
To develop a full understanding of any critical knowledge gaps that may exist, a literature review of the health effects related to coal combustion products will be conducted in 2012. This project will review all exposure pathways related to airborne CCPs (inhalation, ingestion, and dermal contact via settled material) and all types of CCPs. The focus will be on constituents that may pose particular hazards, including crystalline silica and trace metals, and will focus on environmental exposures downwind of storage facilities. As such, the multidisciplinary review will address dispersion, fate and transport, exposure, and toxicity issues. The final deliverable, to be completed in 2012, will be a peer-reviewed scientific journal article that will summarize the state of the science and outline any follow-on research deemed necessary.

Impact
- The project will summarize, in a comprehensive and scientifically rigorous manner, the potential health impacts of CCPs by considering all possible exposure routes and product types.
- The project will outline any knowledge gaps and identify research needed to develop a complete understanding of health issues.
- The project deliverable will aid communication efforts to regulatory, nonprofit, and public stakeholders.

How to Apply Results
Members are encouraged to communicate project results widely. Members should be proactive in sharing results with key stakeholders, ensuring that stakeholders understand the results, and suggesting that results be considered as environmental policies are developed. EPRI staff will work with members and the public to these ends. In addition to member efforts, EPRI researchers will facilitate broader use and awareness of the results by briefing key stakeholders, including regulatory and other government agencies; developing materials for the trade press/media; keeping EPRI’s public website current; and continuing service on various advisory panels.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Critical Review on Health Effects of Coal Combustion Products: A critical review will be published that summarizes known risks and outlines important knowledge gaps related to coal combustion products.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
</tr>
</tbody>
</table>

P92.004 Integration and Synthesis (069218)

Key Research Question
Health concerns drive the regulatory agenda for air pollutants, including fine particulate matter (PM$_{2.5}$) and criteria gases. Determining the differing toxicities of air pollution components is dependent on sound epidemiological, toxicological, and exposure assessment studies. Ultimately, integration across these three
disciplines represents a powerful approach for robust estimates of the health effects of specific air pollution components, sources, or both.

**Approach**

This project will integrate and synthesize epidemiological, toxicological, and exposure assessment research on air pollution and health, conducted by both EPRI and others. The project will emphasize research related to the sources and components of air pollution associated with adverse health impacts. All air pollutants will be included in the scope, but the emphasis will be on PM. Consistency of findings across disciplines will be evaluated, and the state of scientific knowledge regarding the human health impacts of air pollution will be summarized. EPRI results will also be placed in the context of the broader scientific literature. The deliverable will be a peer-reviewed article or EPRI report and will be completed in 2012.

**Impact**

- Integrated and synthesized results can be considered by EPA in its reviews of the NAAQS for criteria gases and PM, which occur every five years.
- Research findings that are common across epidemiology, toxicology, and exposure assessment studies suggest more confidence in the overall results.

**How to Apply Results**

Members are encouraged to communicate project results widely. Members should be proactive in sharing results with key stakeholders, ensuring that stakeholders understand the results, and suggesting that results be considered in environmental policymaking (including standards, state implementation plans, and other regulatory decisions). EPRI staff will work with members and others to these ends. In addition to member efforts, EPRI researchers will facilitate broader use and awareness of the results by briefing key stakeholders, including regulatory and other government agencies; developing materials for the trade press/media; keeping EPRI’s public website current; and continuing service on various advisory panels. Members should review the various communications supplied by EPRI (website summaries, issue briefs, presentation materials) for information that is relevant to their key air quality concerns.

**2012 Products**

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Integrated Analysis of Air Pollution Health Research</strong>: This product will provide an integrated analysis of existing air pollution health research, including epidemiology, exposure assessment, and toxicology research.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
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</table>

**Future Year Products**

<table>
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<tr>
<th>Product Title &amp; Description</th>
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<td>12/31/13</td>
<td>Peer Literature</td>
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</table>
P92.005 Communications (069219)

Key Research Question

It is critical that research results in the air pollution health field be actively communicated to inform the public and other stakeholders. Informing key stakeholders of the latest scientific findings on health issues is extremely valuable, given EPRI’s objective and credible research results and its standing in the scientific community.

Approach

This project will provide succinct descriptions of key research findings and implications on a timely basis. The goal is to provide tools and information to aid members in communicating research findings to lay audiences, such as the popular media, policymakers, and the public. Communications efforts aimed at preparing two-page issue briefs will continue; current briefs will be continually updated and new issue briefs will be prepared as needed. Summaries of the current air quality health literature will be provided twice yearly. Comments on key studies will be prepared and distributed to members in a timely manner. Webcasts will be presented on relevant topics. Presentations to key stakeholders and detailed communications tools will be prepared on an as-needed basis. Special workshops will be convened as appropriate to aid member communication efforts on key air quality issues. Finally, submission of comments on regulatory activities and rulemaking will continue.

Impact

- Results of significant research are effectively communicated to members, the public, the media, regulatory/policy communities, and other stakeholders, thus improving decision making and supporting science-based policy.
- The review of external studies (reports and papers) helps members stay up to date on the latest research findings from other groups.
- This project facilitates informed interaction with decision makers by providing timely and succinct communications materials.

How to Apply Results

Members should review the various communications supplied by EPRI (website summaries, issue briefs, presentation materials) for information that is relevant to their key air quality concerns.

2012 Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Communication Tools: This product consists of a wide variety of communication tools (such as webcasts, issue briefs, and workshops) to aid members in communicating to stakeholders on air quality health issues.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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Future Year Products

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<td>12/31/13</td>
<td>Technical Resource</td>
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</table>
Supplemental Projects

Health Effects of Air Pollution and Particulate Matter Components (072065)

Background, Objectives, and New Learnings

EPA has established National Ambient Air Quality Standards (NAAQS) for fine particulate matter (PM2.5) that assume that all particles in the air, regardless of source or composition, are equally harmful. EPRI pioneered its Aerosol Research and Inhalation Epidemiology Studies (ARIES) to determine which air pollutants in general, and which components of PM2.5 specifically, are affecting human health. This suite of projects is a landmark approach to air pollution research, providing the public and all stakeholders with scientific information about the health effects of PM and other air pollutants and insights into the specific pollution sources affecting public health today. Understanding which pollutants and pollution components are most closely associated with health effects can help regulators identify which sources to control through protective air quality standards.

The Clean Air Act requires periodic review of not only the NAAQS themselves, but also of the science upon which the standards are based. The review process involves obtaining contributions from air quality experts and the public. The objective of ARIES is to investigate (via epidemiology and exposure studies) associations between air quality and human health and to produce results for consideration of the health basis of the NAAQS and for subsequent development of state implementation plans. The ARIES suite of studies currently has ongoing projects in Atlanta, Dallas, Pittsburgh, St. Louis, and Birmingham, Alabama.

Results to date, primarily from Atlanta, suggest that carbon-containing PM components are associated with cardiovascular effects, while some gases, such as ozone and NOx, are more strongly associated with respiratory effects. It is important to undertake studies in several communities as it makes extrapolation of results more universal and as multicity studies are given greater weight by the U.S. Environmental Protection Agency (EPA) in regulatory support analyses.

Project Approach and Summary

ARIES is a multidisciplinary study in which atmospheric research, epidemiology, exposure assessment, health assessment, and statistical modeling have been considered as parts of the whole from the study's inception. The study has four components:

- **Air Quality Characterization**: PM2.5 mass and composition, as well as related gas-phase and particle-phase pollutants, are measured every day in the study city. This comprehensive daily monitoring program has provided epidemiologists with a characterization of aerosol (gas and particle) physical, chemical, and biological (aeroallergenic) properties that had not been available to them before.

- **Air Pollution Mortality**: Daily mortality data are collected from the study city, with a focus on cardiovascular and respiratory deaths.

- **Air Pollution Morbidity**: Daily data on emergency department (ED) visits and hospital admissions are collected from the study city. The focus is on ED visits or hospital admissions for cardiovascular and respiratory endpoints.

- **Statistical Analysis**: Sophisticated statistical techniques are employed to link daily mortality and morbidity to daily measures of air pollution. These epidemiological applications are called multipollutant time-series models.

A unique aspect of ARIES is that it includes multiple epidemiological studies investigating similar health endpoints in the same study population, thus enabling consistency testing. To preclude data mining in support of preconceived ideas, initial analyses are conducted using a priori models for which parameters were established before analysis. The existence of similar studies in several different cities also facilitates meta-analyses, which combine the results across different cities.
Benefits
This research provides an enhanced understanding of the health effects of PM components. It will generate information critical to EPA’s continuing movement toward a multipollutant paradigm and inform consideration of component-specific regulations. Multicity analyses, such as the suite of ARIES cities, will be more informative to regulatory agencies.

Chemistry and Health Effects of Carbonaceous Material in the Atmosphere (072066)

Background, Objectives, and New Learnings
Results to date from EPRI epidemiological research such as ARIES and the Veterans Study, EPRI toxicological research such as the Bi City Concentrated Ambient Particle Study (Bi City CAPS), and non-EPRI research demonstrate significant associations between carbon-containing compounds in the ambient air and adverse health impacts. In addition, recent research has implicated a subset of carbon-containing particles (“brown carbon”) that is light-absorbing. Given these results, there is growing consideration of the need to regulate carbon-containing pollutants. In March 2011 EPA issued a report to the U.S. Congress on black carbon, thereby raising its visibility. At issue is the definition of the carbon compounds responsible for any health effects and how this subset relates to commonly-used measures of carbon in the atmosphere. These issues are important because the extent to which carbon is regulated will influence atmospheric particulate matter concentrations, which in turn will impact the need to limit emissions of non carbon-containing materials such as sulfate.

The objectives of this project are to:

- Compare the existing measurement methods for atmospheric carbon and determine how the measurement metrics relate to subsets of carbon, or specific compounds, found to be associated with health effects.
- Further define the carbon-containing fractions and compounds of particular health relevance. Since carbon-containing particles constitute the largest fraction of particles in most urban atmospheres, the extent to which they are reduced will impact the ability of an area to satisfy standards. This in turn can affect the need to reduce other fractions of PM, such as sulfates or nitrates.
- Evaluate the ability of various particulate fractions to deliver organic materials to the lung. Carbon-containing particles have been shown in some studies to effectively adsorb volatile and semivolatile organic compounds, making them efficient carriers of such compounds. It will be important to contrast the carrying ability of carbon-containing compounds with that of inorganic particles, such as sulfates and nitrates.
- Undertake additional epidemiological analyses to examine the relationship between new definitions or categories of organic compounds and health endpoints, as well as to determine whether there is any epidemiological evidence to support hypotheses about the carrying ability of particles.
- Through detailed characterization - and potentially modeling - of ambient organic compounds, help identify the specific sources of organics, thus aiding stakeholders in their decisions regarding the sources warranting greater regulatory attention.

Project Approach and Summary
This multidisciplinary project involves measurement, characterization, epidemiological analyses, and toxicological analyses. The project will characterize carbon-containing compounds in ambient air and relate them to the various measurements that are currently available and have been used in air pollution health studies. The research will also examine the totality of measurements of carbon-containing compounds in EPRI datasets (ARIES, the Children's Air Pollution Asthma Study, Bi City CAPS, and others) and undertake further analyses that will help indicate the specific fractions of carbon-containing compounds associated with adverse health effects. Toxicological studies will be carried out to determine if any compounds implicated in the epidemiological analyses are supported from a mechanistic perspective, and to help define the classes of compounds of concern. Particular attention will be granted to examining the "carrying capacity" of various particulate matter components with respect to delivery of semivolatile or volatile organics. Additional toxicology research will be carried out to evaluate primary versus secondary particles. A review of the vast occupational
health literature will be conducted, and a culminating workshop will be held at which EPRI results will be shared and discussed with other researchers and key stakeholders.

Benefits

This interdisciplinary umbrella of research will play a pivotal role in increasing our understanding of the chemistry and health effects of carbonaceous materials in the atmosphere. This research will help inform the public and provide updates on conditions which may potentially impact human health and the environment. While these materials represent the major fraction of PM in many urban areas and a significant fraction in other areas, there is a lack of information regarding sources and toxicological effects. It is conceivable that carbon-containing materials will be regulated in the future; such regulatory actions will influence PM concentrations and consequently the need to regulate non carbon-containing components such as sulfate. For effective regulation, additional information regarding the health effects of carbon fractions as well as specific organic compounds is critical. In addition, the project will generate scientifically sound data regarding the "carrying capacity" of carbon as well as other PM components, a key issue from a toxicological perspective.

It should be noted that existing chemical characterization and health data collected as part of EPRI projects represent one of the richest datasets in the world. In this way, the project leverages substantial previous investment on the part of EPRI, its members, and other funding organizations.
Environmental Aspects of Renewable Energy - Program 179

Program Overview

Program Description
Renewable energy technologies use a variety of means to harvest energy from the natural world and transform it for human use. As the world moves to a more rapid expansion of renewable technologies for electricity production, the opportunity exists to build an understanding of the overall impact of these technologies and to use that understanding in planning, siting, and operation of renewable energy infrastructure. Many proposed renewable energy projects have not gone forward due to concerns over impacts on the environment, ecosystems, species, or human health and safety. In some cases, there is a lack of scientific research to answer questions that are important to these decisions. With a comprehensive understanding of all the impacts, efforts to minimize the overall environmental footprint and optimize the environmental benefits of a renewable energy portfolio can be made.

There are many environmental aspects of renewable energy, such as land use, vegetation management, and species interactions. Some of these aspects are opportunities and some are challenges or limitations. The Electric Power Research Institute's (EPRI's) Environmental Aspects of Renewable Energy program conducts a body of work to maximize the opportunities and minimize the limitations of renewable energy deployment. EPRI will characterize the resources and develop an understanding of the limitations of harvesting those resources. Results will provide valuable input to siting and planning activities, operations, and maintenance of renewable generation. EPRI's vision for its Environmental Aspects of Renewable Energy program is to address public and environmental concerns associated with renewable energy development.

Research Value
Renewable technologies are a rapidly growing source of electricity generation and a key strategy for diversifying generation portfolios. While some renewables are mature and others are still developing, the environmental aspects of renewable energy development are not well understood. As companies plan new renewables projects, they must develop strategies for compliance with renewable portfolio standards (where applicable) or other potential renewable energy requirements. Companies must be assured that development plans can be implemented in a timely and environmentally responsible manner. Company plans must also address other issues affecting human health and the environment, which may limit the ability to permit or operate a facility. This program will

- assemble a knowledge base of existing research on environmental aspects of renewable energy, advance scientific learning, and identify research gaps;
- prioritize research needs and develop strategies to sustainably implement renewables; and
- provide valuable input to siting and planning activities.

Approach
The expanded use of renewable energy is driven by its environmental benefits, yet concerns remain about potential impacts related to specific projects and wide-scale deployment. This program provides research, data, analyses, and expertise to help address environmental concerns about renewable energy development. Program activities are based on prioritization and available funding, but are expected to include work such as

- development and testing of mathematical models to manage impacts of renewables on endangered and protected species,
- assessments to characterize and forecast renewable fuel resources,
- assessment of the impacts of large-scale deployment of renewables on climate variables,
- development of tools for siting renewable energy assets,
- development of a bat detection and shutdown system,
development of a framework for assessing the long-term sustainability of biomass supply, 
life-cycle impact analyses of renewable technologies, and 
assessments of renewable technology electric and magnetic fields exposures and potential effects on 
animals and marine life.

Accomplishments

EPRI's Environmental Aspects of Renewable Energy Interest Group marked the beginning of this research area 
in 2010. The interest group identified and prioritized research needs, exchanged best practices, and examined 
successful approaches. Results from the interest group laid the foundation for a robust and relevant body of 
research, addressing issues of critical concern for this program to examine. The program came into existence in 
2011 and worked on wind/noise issues, bat detection, and species modeling approaches.

Current Year Activities

Program R&D for 2012 will focus on the following:

- Clarifying various impacts of renewable energy technologies through literature reviews, case studies, and 
  new research 
- Exploring mitigation approaches to minimize the environmental impacts of renewable energy technologies 
- Evaluating the potential effects of large-scale deployment of renewables 
- Quantifying life-cycle impacts and accelerating technologies with less impact

Estimated 2012 Program Funding

$2.0M

Program Manager

Tina Taylor, 650-855-2369, tmtaylor@epri.com

Summary of Projects

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P179.001</td>
<td>Species Impacts and Interactions</td>
<td>Renewable technologies have the potential to impact animal and plant populations either directly or indirectly. This project will explore the interactions between equipment and species, develop approaches to minimizing impacts, and evaluate the effects those impacts might have on species populations. The project will also examine how renewable technologies impact land use and land use change.</td>
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<tr>
<td>P179.002</td>
<td>Resource Assessments, Forecasting and Land Use</td>
<td>A key element of renewable technologies is that they use energy sources already in the natural environment in place of traditional fuels. As the world increasingly depends on the environment as its energy source, characterizing and forecasting the availability and behavior of those resources becomes increasingly important. This project will develop methods to assess present resources and review how they might change in the future.</td>
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<tr>
<td>P179.003</td>
<td>Worker / Public Health and Safety</td>
<td>As the proliferation of renewable energy equipment continues, many more workers will be performing new types of activities involved in the construction, operation, and maintenance of new types of facilities. Additionally, the public has had questions and concerns related to the potential impacts of new types of generating technologies. This project will create a base of knowledge and seek to identify the most protective, best practices that can be widely applied.</td>
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P179.004 Siting and Life-Cycle Analysis

Siting of renewable energy needs to take into consideration the location of the resource, proximity to infrastructure, and stakeholder concerns. The life-cycle impacts of various technologies will be examined and an approach will be developed for incorporating technical and stakeholder considerations into siting decisions.

P179.001 Species Impacts and Interactions (070646)

Key Research Question
Renewable technologies have the potential to impact animal and plant populations either directly (for example, bird collisions with and bat barotrauma from wind turbines) or indirectly (for example, habitat disturbance by central station solar power plants). There are many unknowns about how these interactions will affect species populations, what adaptive measures can be employed, and how alternative approaches compare.

These concerns frequently result in requests for additional studies or information, and thus in delays during planning and siting activities or in reduced windows of operation for the equipment. This research will develop information and tools to eliminate or minimize species impacts.

Approach
The project objective is to manage population reduction risk for all animal species, particularly endangered and protected populations that may be affected by renewable technologies. Management options may include facility designs, new technology application, operational changes, and alternative siting configurations.

EPRI has a long history of risk modeling and individual-based population modeling. These models can be used to assess and manage population risk associated with both direct mortality and habitat modification.

Additional work will be done to gain a better understanding of the ways in which species interact with equipment and to seek improved approaches. One example is the development of a bat detection and shutdown system for wind turbines.

Impact
The tools developed and tested by this project will expedite the siting, construction, and licensing of renewable power installations and may allow for greater operating windows, hence reducing cost and accelerating revenue production. In particular, this research should have application to wind farms, central solar power plants, and large-scale photovoltaic systems.

How to Apply Results
Results from this project may be applied to help determine the best places to site new technology; to inform stakeholders during planning, siting, and permitting activities; and potentially to improve equipment design or operational controls.

2012 Products

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<th>Product Title &amp; Description</th>
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<tr>
<td>Bird and Bat Population Modeling With Wind Energy: This project will develop and test mathematical models to assess and manage animal population risk to species of concern, particularly endangered and protected populations, from renewable technologies. Management options may include facility designs and siting. In 2011–2012, a study will be conducted to produce a risk assessment/management framework for bird and bat population</td>
<td>09/30/12</td>
<td>Technical Report</td>
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interactions with wind turbine facilities. The framework will use a RAMAS Monte Carlo simulation model that will accept GIS-based information on installation placement and habitat structure. The framework will allow estimates of risk of decline of local and migratory populations under hypothetical and empirically parameterized scenarios. In subsequent years, the risk modeling approach will be applied to central station solar power plants.

**Bat Detection and Shutdown System:** If initial research is successful, the shutdown system will be field tested and operational protocols developed. Demonstrations may be performed as supplemental projects.

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<td>10/31/12</td>
<td>Technical Report</td>
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**Future Year Products**

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<tr>
<td><strong>Species Population Modeling With Central Station Solar:</strong> This project will develop and test mathematical models to assess and manage population reduction and extinction risk to endangered and protected populations from renewable technologies. Management options may include facility designs and siting. In 2012–2013, this approach will be applied to solar facilities. The framework will use a RAMAS Monte Carlo simulation model that will accept GIS-based information on installation placement and habitat structure. The framework will allow estimates of risk of decline of local and migratory populations under hypothetical and empirically parameterized scenarios.</td>
<td>06/30/13</td>
<td>Technical Report</td>
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**P179.002 Resource Assessments, Forecasting and Land Use (070647)**

**Key Research Question**

A key element of renewable technologies is that they use energy contained in the wind, sun, and water as energy sources in place of traditional fuels that rely on combustion to extract the energy. As the world increases its dependence on the environment as its energy source, characterizing and forecasting the availability and behavior of those resources becomes increasingly important.

**Approach**

This area of work will assess the existing resources and explore changes to the resources that might occur naturally or as a result of harvesting the energy at large scale. This project will produce a national assessment of changes in wind, solar insolation, and water availability that might be expected under future scenarios. Causes of change could include climate variability, population growth, and land use changes.

**Impact**

Better understanding of the risks to and potential variability of the energy in the environment as a fuel source for renewable technologies will allow optimized planning for maximum energy harvesting at a sustainable level.

**How to Apply Results**

Results from this body of work will inform planning processes, help to define limitations on renewable energy deployment, and address stakeholder concerns.
2012 Products

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<tr>
<td><strong>Sustainability of Biomass Supply</strong>: This project will develop a framework for assessing the long-term sustainability of the supply of biomass. The initial phase of the project will analyze biopower supplies in the context of regional and national policies such as renewable portfolio standards and greenhouse gas legislation. A national modeling platform with regional resolution will be used to evaluate biomass feedstock supplies under alternative conditions—for example, different policies (climate, energy, and other), markets, grid integration, public lands management, and plant types. With the framework developed, it will be possible to perform power plant–level analyses as supplemental projects.</td>
<td>08/30/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Resource Variability</strong>: This project will produce a national assessment of changes in wind, insolation, and water availability that might be expected under future scenarios, which could include climate variability, population growth, and land use changes.</td>
<td>10/30/12</td>
<td>Technical Report</td>
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**P179.003 Worker / Public Health and Safety (070648)**

**Key Research Question**

As proliferation of renewable energy electric generation technologies continues, many more workers will be performing new types of activities involved in the construction, operation, and maintenance of new types of facilities. There is a need to understand the most protective, best practices that can be widely applied to minimize workplace injuries and accidents. Additionally, the public has questions and concerns related to the potential impacts of new types of generating technologies.

**Approach**

EPRI has a long history of examining health and safety issues related to construction, operation, and maintenance of traditional electric system infrastructure and will apply similar approaches to the questions and concerns related to new infrastructure. These approaches include ergonomic interventions, measurements and modeling, and human health studies.

Noise from wind turbines will be measured, including infrasound, along with surveys of people living nearby, to create a scientifically based information set on these impacts.

**Impact**

The goal of this work is to improve worker safety and address public concerns about implementation of renewable technologies.

**How to Apply Results**

The results of this research may result in new suggested work practices, which could be adopted in procedures. Other work may yield information to be shared with the public to help communicate about concerns that are raised.
P179.004 Siting and Life-Cycle Analysis (070649)

Key Research Question
Many proposed renewable energy projects have been delayed or not gone forward due to concerns over impacts on the environment, ecosystems, species, or human health and safety. In some cases, there is a lack of scientific research to answer questions that are important to these decisions. In other cases, there is no framework to constructively allow a large number of constituents to engage in decision making that include both technical and environmental concerns.

Approach
Life-cycle impacts of various technologies on water and land will be explored and documented. Published literature and actual project information will be used to characterize the use.

Building on results of a supplemental project that is developing a framework for siting, continued research will provide supporting data and document case studies.

Impact
A framework for decision making along with a good base of factual information will facilitate consideration of all potential impacts and options at the beginning of a planning cycle. Such a framework and information will result in plans that have stronger support and a better probability of moving to completion in a timely manner.

How to Apply Results
The information developed and gathered during this research will be available to program members to support decision making and communication with various stakeholders, including the public. The siting framework can be applied on a project-specific basis as a means of involving many stakeholders in the planning process.

2012 Products

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<tr>
<td>Life-Cycle Land Use From Power Generating Technologies: Reviewing published information, this project will provide an overall view of land use from various energy generation technologies.</td>
<td>03/30/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Demonstration of Siting Framework for Concentrating Solar Station: In conjunction with one or more members, the siting framework developed will be used to evaluate siting options for a central station solar facility. A technical report will summarize the results of that process.</td>
<td>08/30/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Life-Cycle Water Use From Power Generating Technologies: Reviewing published information, this project will provide an overall view of water use from various renewable electric energy generation technologies.</td>
<td>09/30/12</td>
<td>Technical Report</td>
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<td>Demonstration of Siting Framework for Wind: In conjunction with one or more members, the siting framework developed will be used to evaluate siting options for onshore or offshore wind technology. A technical report will summarize the results of that process.</td>
<td>02/28/13</td>
<td>Technical Report</td>
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<td>Product Title &amp; Description</td>
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<tr>
<td><strong>Demonstration of Siting Framework for Biomass:</strong> In conjunction with one or more members, the siting framework developed will be used to evaluate siting options for a biomass facility. A technical report will summarize the results of that process.</td>
<td>09/30/13</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>
Supplemental Projects

Managing Species Issues For Renewables (072110)

Background, Objectives, and New Learnings

Renewable energy now accounts for a significant portion of recently installed generation capacity, of which wind energy represents the majority. As wind development increases, there is a direct increase in the associated impacts on resident avian species of a given resource area. Any identified potential impact may suggest a long-term risk to the survival of a local avian population. To aid development, developers must take new approaches to manage any potential species impacts before building a wind energy development. Absence of these assessments could result in extended project timelines due to additional pre- and post-construction studies, higher project costs due to mandatory mitigation efforts, lower return on investment due to operational curtailment, and potentially the cancellation of projects which can lead to potential difficulty in reaching state mandated renewable portfolio standards.

Utility-scale renewable energy projects must satisfy intense concerns regarding a number of risks, including impacts on wildlife. Based on ongoing EPRI research, the current primary wildlife impact focus for wind energy development is the prediction of annual bird fatalities from blade strikes. These predictions are used in the formulation of take permits and mitigation measures according to guidelines set by state and federal agencies. This information may also assist potential lenders who want to assess the long-term risk of investment. Despite this primary focus, all documents offering considered guidance on the assessment of wind energy impacts on wildlife (for example, documents from the National Wind Coordinating Council and the U.S. Fish and Wildlife Service [USFWS]) suggest that population-level impacts should also be modeled. There is also a strong shift toward the use of adaptive management, which the FWS defines as a proactive cycle of population modeling, monitoring, and mitigation.

Current legislation mandates that projects must have an "incidental take permit" to address the potential "take" of bald or golden eagles. Take is defined by the USFWS as to "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb." This permitting requirement requires wind developers to take an active part in the resource development of a given area of build out. A more comprehensive population modeling approach is strongly recommended to establish an improved understanding of wind energy’s impacts on eagle species, with the intent to provide guidance on the most difficult siting issues related to species management. Species-level impacts provide a more accurate assessment of the ecological impacts of wind energy than the current practice of monitoring single mortality events.

Eagles are protected under the Bald and Golden Eagle Protection Act. Therefore, it is against current policy (as defined by the USFWS) to offer an incidental take permit for either of these species of eagles. This permitting conundrum has led to significant frustration on the part of regulators, wind developers, and power purchasers, creating a risk for projects moving forward toward operation. Because these projects may be in violation if a mortality event occurs, such an event can create a federal liability for the owner/operator of the wind facility.

This inherent confusion facilitates the need to understand the population level impact associated with wind deployment on eagle species. Such an understanding would provide a basis for the development of complimentary regulation, facilitating both the protection of eagle species and the deployment of wind energy. This understanding would also be beneficial in developing effective "adaptive mitigation" strategies, strategies employed based on site specific population impacts, that could be used in the future. This approach will help inform utilities, developers, and regulators and the public in general on how to minimize species impact risks attributable to wind energy project development prior to roll out of the infrastructure in a particular region.
Project Approach and Summary

The RAMAS software is designed to link GIS-generated landscape data to a "metapopulation" (a group of spatially separated populations of the same species which interact at some level) model for extinction risk assessment, viability analysis, reserve design and wildlife management. The software includes facilities for modeling life-stage-specific impacts and spatially explicit population dynamics linked to GIS inputs such as habitat suitability and development footprints. This model can then be run to simulate future changes in the abundance of the species and its distribution in the landscape, to estimate the risk of extinction or decline, time to extinction and other measures of threat and viability. The major advantages to RAMAS software are its transparency, automatic error checking, and international acceptance by regulatory agencies and conservation groups. RAMAS software embraces uncertainty using stochastic simulations and sensitivity analysis. Model outputs are delivered in terms of risk.

This study will develop baseline and impacted population models. The work will address issues specific to the wind resource area, as determined by the needs of the collaborator. We suggest studying operating wind farms and sited areas to make comparisons in population impact at a larger (e.g. 10,000 km²) spatial scale and accounting for the effect on migratory eagles. The former can be accomplished using a map-based habitat suitability model to delineate the spatial structure and dispersal pathways of subpopulations in the vicinity of the wind farm. The latter can be addressed using information on land features and migratory behavior to identify the geographic origin of migrants (such as eastern Canada), a habitat suitability model to estimate the carrying capacity of that region, and stage-specific turbine-related fatality data.

Benefits

A full range of risk estimates for migrant eagles can be obtained by varying assumptions about population density and the geographic scope of impact. An understanding of the population-level impacts of wind energy development on eagles will provide greater insight into required mitigation efforts. Such an understanding could provide additional justification for projects with minimal impact and may facilitate reevaluation of high-risk projects before development costs become too significant to re-site. This type of knowledge will also add certainty to long-term operations and provide "adaptive mitigation" strategies.
Wind Noise and Health Impacts (071149)

Background, Objectives, and New Learnings
Renewables are the fastest-growing clean energy resource, and wind power is expanding more rapidly than other technologies. Some environmental and health risks—such as ultra-low frequency sound (infrasound) causing annoyance and possible adverse health effects—are perceived by the public to be associated with wind development. Some proposed wind energy projects have not gone forward due to these concerns.

This project represents an umbrella of research activities to inform policymakers and other stakeholders on the impacts of wind turbine–related noise.

Project Approach and Summary
This project consists of a comprehensive evaluation of wind turbine–related noise and potential community impacts, involving preparation of a state-of-the-science critical review, laboratory research on the potential biological effects of infrasound and other low-frequency sound, and field-based research to measure sound from operating turbines. The field research also includes an evaluation of public perceptions of turbines and potential health issue. The research is unique in that residential sound exposures will be measured and therefore correlations with complaints can be evaluated.

EPRI is starting one major field project in the Northeast and intends to carry out similar studies in the Midwestern U.S./Canadian region and the Texas/Southeast region. This work will create technology transfer opportunities for project participants, who may benefit from others’ experiences. EPRI is seeking project participants from all regions.

Benefits
More data are needed to evaluate whether audible or subaudible sounds emitted by wind turbines have any direct adverse physiological effects on people living or working near wind farms. Studies of existing wind projects can help decision making for future operations in other regions. In some cases, wind projects may be influenced by unique terrain and weather patterns, which will be factored into this study. Gaining an understanding of public perception near wind projects is the first step in developing strategies to mitigate risk for utilities and the public. This study will provide data that will allow officials to better understand the nature and origin of noise complaints. Laboratory-based research will serve a critical role in examining in a scientifically rigorous manner the potential biological impacts of infrasound and low-frequency sound.

The research findings from this project are expected to generate data critical to informing regional, state, and local officials about how wind development may affect existing communities. This work also should help wind operators communicate more effectively any potential risks, as well as develop siting criteria to minimize risks.
Evaluation of Algae Bioenergy Technologies (071823)

Background, Objectives, and New Learnings

Microalgae (microscopic algae) are unicellular plant species that transform water, sunlight, carbon dioxide (CO₂), and a variety of nutrients into biomass. This biomass is composed of lipids, carbohydrates, and proteins, each of which can be converted into salable products or fuels. The lipid fraction is of great interest as a feedstock for the production of biologically derived (biogenic) diesel, gasoline, and jet fuels. Algal bio-mass solids or derived fuels may be processed and used—alone or in combination with other fuels—in power plants and combined heat and power systems. However, there is considerable uncertainty as to whether algal bioenergy technologies are affordable, scalable, and operationally robust approaches for displacing significant amounts of conventional fossil fuels.

Growing algae at industrial scale requires high biomass productivity rates, beyond what is achievable by algal cells extracting CO₂ directly from the atmosphere. Thus, concentrated streams of CO₂ such as power plant flue gas represent promising sources for promoting the growth of algae at high-volume production scale. Colocated algae production has been proposed as an attractive source of CO₂ for algae producers and touted as a means for mitigating atmospheric release of carbon from the host power plant. However, the carbon converted into biomass and then into fuel would eventually be released to the atmosphere. Thus the net impact on CO₂ emissions depends on how much petroleum-based fuel is displaced by its biogenic alternative. Another factor is calculating the difference in CO₂ emissions between the extraction, refining, transportation, and use of the conventional fuel and the growth, harvesting, refining, and use of the algal fuel. This calculation requires detailed process modeling, energy and carbon balance calculations, and life-cycle analyses. At present, algae technologies are unlikely to be a large-scale solution for CO₂ recycling. However, technological advances could improve the necessary algal characteristics and growth systems for increased amounts of biomass production and carbon uptake. Additionally, integrating algae growth systems with wastewater treatment or creating other products may provide additional benefits or revenue to power plants.

Project Approach and Summary

This project will provide quantitative and qualitative analyses of large-scale algal bioenergy technologies that are connected to power plants. These technologies could include, but are not limited to, production of algal biomass for use in creating liquid transportation fuels, high-value chemical feedstock, animal feeds and fertilizers, and biogas. EPRI will provide information on integration, sustainability, and life-cycle issues while identifying concepts that merit further R&D and real-world demonstration.

A model originally developed through the EPRI Technology Innovation program (Utility-Connected Algae Systems Model) will be used to determine net energy and carbon requirements and to provide financial estimates of the technologies evaluated. This project will also develop additional model functionality for estimating potential benefits to the power plant, such as gasification of algal biomass, or for transportation of the products.

Benefits

This project will develop a flexible framework to perform comparative analyses of algae systems. Specific benefits are expected to include a transparent engineering process-based evaluation of a number of algal bioenergy technologies that are connected to power plants based on reliable and realistic parameters. The results may be used to estimate the impact of algae systems on power plants, determining performance criteria for use in energy production at power plants and beyond. The public may benefit through reduced emissions of greenhouse gases through the use of biologically-based fuels as a substitute for fossil fuels.
Sustainable Maritime Ports (071348)

Background, Objectives, and New Learnings

In a recent EPRI survey, maritime ports and related organizations consistently reported that sustainability is a critical factor in meeting continued growth in international maritime trade. Ports that do not embrace sustainable activities such as managing air quality, managing wastewater issues, and using carbon-neutral energy sources to run equipment (for example, cargo handling and dredging), rail, and trucking for port operations may see increased operating and maintenance costs or a limited ability to expand or remain secure in the future. To address these issues, EPRI will assess the state of the port industry and identify opportunities to effectively address these challenges. This collaborative effort seeks participation from ports nationwide and utilities with interest in helping ports to quantify potential improvements associated with adopting sustainable growth strategies and determining ways to put these strategies into practice.

Typically, local, national, and global challenges drive maritime ports to prioritize and improve air quality and GHG emissions, water management, and waste materials management. This research project provides port systems with an opportunity to take a holistic view of their emissions impacts and long-term risks associated with current operations and management scenarios. Clean fuel and truck programs, green buildings, and integrated on- and offshore renewable power supplies maybe implemented as significant environmental improvement of operations over time.

Project Approach and Summary

This project will be a collaborative assessment of carbon, water, and waste management operations at maritime ports. Key opportunities exist for improving the carbon footprint and other environmental impacts of port operations. The goal of this project is to take a systems-based approach to evaluating which improved practices will most significantly lower operating costs, improve efficiencies, and minimize impact to the environment. The following areas will be targeted:

- Air quality and GHG emissions from transportation (trucks, rail, and vessels if applicable) and cargo-handling equipment
- Water and wastewater management and movement (pumping) from on-site treatment facilities
- Ecological solutions for dredged materials
- Green/net-zero building design
- Brown- to greenfield redevelopment
- Renewables integration, automation, and control systems

Target areas to be assessed will be chosen by the project collaborative based on funder input and agreements on scope. Technical potential will be evaluated by comparing the opportunities for improvement identified at each location against a base case established through site characterization. Specific tasks will include

- review of current practices for each target area with regard to environmental and economic sustainability,
- assessment of technical potential for improvement in each target area based on identifying a cleaner energy system, and
- prioritization of practices of greatest impact through the evaluation of local, regional, national, and other external drivers based on projected policy forecasts and changes in energy supply within a region.

Benefits

An in-depth understanding of technologies and infrastructure synergies that reduce operational risk and improve the economics of lowering a port’s carbon footprint and other environmental impacts may provide opportunities for reducing costs and promoting long-term growth. These improvements may require upgrades to existing facilities or construction of environmentally friendly commercial and industrial infrastructure to move goods within a port system. Solutions could include finding innovative means of electrifying equipment—rail, trucking, and even dredging operations—that lead to operational efficiencies, while simultaneously reducing GHG emissions and managing wastewater. These opportunities are anticipated to have long-term benefits, especially in a changing regulatory and fuel supply landscape. This project may benefit the public from alternative means of managing water, waste and carbon, potentially resulting in less contaminants flowing to streams and less emissions in the vicinity of port systems.
Energy Sustainability Interest Group 2012 (066626)

Background, Objectives, and New Learnings
Growing attention on corporate transparency, disclosure, and opportunities to improve sustainability performance are driving increasing investment and interest in related research. Financial and credit markets are increasingly using environmental and social measures alongside economic metrics as a factor in valuing and determining investment risk for a company. For over 10 years, international reporting efforts like the Global Reporting Initiative, Dow Jones Sustainability Indexes, and Carbon Disclosure Project have been encouraging transparency on sustainability-based issues. Most recently, the U.S. Environmental Protection Agency began formally investigating an operational framework for sustainability that applies across all of the Agency’s programs, policies, and actions.

Electric power companies face unique challenges and tradeoffs. They are expected to manage financial, environmental, and social performance while providing safe, clean, reliable, and affordable power. However, power companies are not fully realizing the opportunity to optimize company decisions, inform public and stakeholder priorities, and shape future regulatory initiatives. Electric power companies will achieve enduring growth and superior long-term financial performance by thoughtfully addressing the social, economic, and environmental needs of present and future generations.

Project Approach and Summary
Interest group members will guide discussion topics and research projects. EPRI will organize meetings, conference calls, webcasts, and other means of communication. The following areas of interest have been identified, and additional topics to be addressed will be identified by members of the interest group:

Collaboratively Advance Industry Sustainability
- Maintain an industry forum including facilitated discussions, presentations, and engagement with industry experts to exchange best practices, identify emerging issues, and discuss common sustainability challenges

Understand Sustainability Priorities and Indicators
- Facilitate evaluation of industry economic, social, and environmental sustainability priorities and indicators
- Inform and support communication with third-party reporting and rating organizations, agencies, and stakeholders
- Investigate best practices to improve performance on key indicators

Explore Tradeoffs and Interdependencies
- Explore decision tradeoffs and opportunities to optimize industry decisions

Benefits
The Energy Sustainability Interest Group was launched in 2008 and is made up of nearly 30 companies. This collaborative group represents a well-rounded cross-section of the electric power industry and continues to draw increasing interest. The group meets regularly throughout the year by webcast and conference call, as well as for two workshops. These interactions allow the exchange of information that can improve company performance, inform external reporting mechanisms, and strengthen public communication.

The Energy Sustainability Interest Group’s continuing purpose is to create business value while driving innovation and collaboration. In 2012, the interest group will highlight understanding of the complex tradeoffs in corporate decision making. The 2012 interest group will also convene to discuss scoping future actionable projects or a future program to research industry issues and provide mutual benefits to society.

Achieving a robust energy economy requires managing the global sustainability challenge: enabling universal access to affordable electricity combined with environmentally sound power generation, transmission, and delivery options (EPRI, 1997). Financial and credit markets are increasingly using the measure of sustainability as a factor in valuing a company. Market research has shown that sustainable companies have competitive advantages with customers and employees. Acting sustainably improves relationships with all stakeholders and can create new business opportunities. Since 2008, the industry has benefited by engaging in discussions and sharing information about what it can do to improve sustainability and develop common strategies to shape such a future.
Global Climate Policy Costs and Benefits - Program 102

Program Overview

Program Description

How international and domestic climate policies are implemented may change the cost to the global economy by trillions of dollars. While international climate policy discussions have slowed and U.S. federal policy no longer appears imminent, the issue and fundamental challenges to the electric power industry appear largely unchanged. The unique scientific, economic, and technological concerns of the electricity sector are critical to the policy debate, and research is essential to informing stakeholder discussions over both the fundamental form and the details of policy proposals. Building the understanding and institutional capacity to implement efficient policies to reduce greenhouse gas (GHG) emissions will take years. The current lull in U.S. federal climate policy activity provides an opportunity to develop the knowledge base and understanding needed to make effective choices when policymakers decide to act. Cost-effective implementation coupled with technology advances can substantially reduce the cost of achieving the environmental objectives of these policies.

The Global Climate Policy Costs and Benefits program provides members and public- and private-sector decision makers with analysis and information on the potential costs and benefits of domestic and international global climate policy proposals. The program’s modeling and analysis provide local, state, national, and international policymakers with crucial information for making economically and environmentally sound climate policy decisions; they also inform members of the possible implications of different policy choices, helping them make better decisions. The research focuses on estimating the economic costs of climate policy proposals against the backdrop of other energy, environmental, and economic policies; identifying policy principles for reducing these costs; and comparing these potential costs with the potential benefits of lower GHG concentrations, taking into account the role of uncertainty. The research also examines the role of technology advances in limiting policy costs and explores the role of domestic and international offsets as a cost-effective compliance strategy.

Activities in the Electric Power Research Institute's (EPRI’s) Global Climate Policy Costs and Benefits program (P102) described here complement activities in the Greenhouse Gas Reduction Options program (P103). P103 examines energy, environment, and climate issues from a utility-level perspective, often considering choices, implications, and actions down to the individual generating unit level. In addition, P103 research examines key details of climate policy—such as alternative accounting procedures for GHG emissions offsets or what buyer liability might mean for a trading scheme—and has often provided a neutral forum for stakeholder discussions of key issues. P103 results are typically communicated via workshops and EPRI technical reports, with less emphasis on publishing results in peer-reviewed journals. P102 research takes a complementary view, providing critical insights into global, national, and regional climate policy choices—choices that define the context in which companies will have to make decisions. P102 provides ongoing support of modeling frameworks internally and at the Massachusetts Institute of Technology and Battelle Pacific Northwest National Laboratory in order to inform policy discussions. P102 staff members are active participants in the Intergovernmental Panel on Climate Change (IPCC) and in National Academy of Science (NAS) panels, and almost all of P102’s results are published in peer-reviewed journals. Together, the two programs provide an integrated, consistent view of energy and climate policies and company strategies from a variety of vantage points.

Research Value

Climate policies will fundamentally change the economics of electricity and energy, and smart policy approaches can substantially reduce the costs of meeting the environmental goals of these policies. This program’s primary value is its ability to provide integrated assessments of potential costs and benefits of climate change management proposals and to examine the impacts on national and international economies. Within these analyses, the program illuminates the role of technology advances in achieving climate policy goals, with a
Electric Power Research Institute 2012 Research Portfolio

specific emphasis on the electricity sector. The program’s nationally and internationally recognized experts are able to bridge gaps between the technical and policy communities. This research provides

- a highly respected and valuable source of information and analysis to U.S. decision makers and the global modeling community;
- efficient and thoughtful design principles to inform regional, national, and international policy debates; and
- a strong analytical basis for the representation of electric utility industry issues in climate policy discussions.

Approach

The program informs the public policy process by communicating research results to the broadest possible audience. The program develops detailed insights that are published in peer-reviewed literature. The program also communicates key messages from this work via issue briefs, newsletters, Congressional testimony, and briefings for stakeholders, policymakers, researchers, and the press/media. This program delivers

- high-profile messages on the value of technology in climate policy discussions,
- scenario analyses through analytical models,
- study results for program members to use in presentation materials for internal and external communications, and
- program experts that provide expertise to the domestic and international climate science and policy communities.

Accomplishments

Program accomplishments include the following:

- IPCC reports and other publications highlight EPRI research on the importance of climate policy flexibility to the electric sector and society.
- The U.S. Climate Change Science Program uses three EPRI-supported models for scenario analysis.
- Research on the value of technology development informs research and development investment decisions.
- Research on developing-country emissions and the implications of coalitions of countries agreeing to climate policy has helped inform international negotiations.
- EPRI experts are playing key roles in informing U.S. climate change research priorities, in the NAS America’s Climate Choices study, and in the IPCC’s forthcoming Fifth Assessment Report.

Current Year Activities

Program R&D for 2012 will continue to focus on informing climate policy at the regional, national, and international levels. However, the range of policies considered will broaden significantly to reflect renewed interest in regulatory approaches to complement or replace the market-based policies that have dominated climate policy discussions for the past two decades. Collaboration with programs in EPRI's Generation Sector and Power Delivery and Utilization Sector (for example, energy efficiency and electric transportation) will be crucial to providing comprehensive climate policy analysis. Specific efforts will include

- analysis of the costs of specific proposed climate policies at the regional, national, and international levels to inform policy negotiations, with an emphasis on understanding the implications of market-based versus regulatory approaches;
- integrated assessment of potential costs and benefits of alternative climate change management proposals, with an expanded focus on the contribution of aerosol emissions;
- examination of the role of technology and electrification in achieving climate policy goals, with more detailed assessments of renewable resources; and
- continued development of U.S. regional modeling capability to assess domestic climate policy details.
Estimated 2012 Program Funding
$2.6M

Program Manager
Geoffrey Blanford, 650-855-2126, gblanford@epri.com

Summary of Projects

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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P102.001</td>
<td>Climate Policy Design, Implementation, and Costs</td>
<td>This project improves understanding of what constitutes cost-effective climate policy. Research includes analysis of the elements of alternative policy designs (for example, market approaches versus regulatory controls) and implementation, as well as estimates of the economic costs at various levels of achieving GHG emission reductions specified in prominent climate change policy proposals. This work also elucidates the role of the electric power sector under various policy alternatives, with new emphasis on regional specificity in the U.S. national context and the potential role of offsets in reducing national compliance costs.</td>
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<tr>
<td>P102.002</td>
<td>Integrated Assessment of Costs and Benefits of Climate Change Management Proposals</td>
<td>This project uses information developed about the costs and benefits (damages avoided) of proposed climate change proposals to objectively facilitate economically and environmentally sound policies. The frameworks developed for this integration will be continuously refined and updated with new methods and information, taking into account changes in knowledge about the future character of the energy and economic system, climate-relevant physical processes, and new proposals in the evolving debate. Expanded emphasis will be placed on the characterization and treatment of uncertainty.</td>
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<tr>
<td>P102.003</td>
<td>The Role of Technology in Managing Climate Change</td>
<td>Technology is the key to the transition to a low-carbon future. An effective technology policy that speeds development and demonstration of technological advances can dramatically reduce the cost of meeting any prescribed emissions reduction goal. Using EPRI-sponsored models, this project will examine the role of technological advances in managing the costs of climate change policy compliance. In particular, this research highlights the opportunity for decarbonization of the economy through electrification. Added emphasis will be on exploring the potential role of renewables and energy efficiency improvements in a carbon-constrained world.</td>
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<tr>
<td>P102.004</td>
<td>Communications</td>
<td>Effective communication is the key to getting value from this program. This project funds efforts to communicate key insights to members, key stakeholders, and the public through workshops, the Annual Climate Seminar, issue briefs, newsletters, and <a href="http://www.epri.com">www.epri.com</a>.</td>
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P102.001 Climate Policy Design, Implementation, and Costs (SP0294)

Key Research Question
Estimates of the economic costs of reducing GHG emissions at the regional, national, and international levels are needed to help inform global climate change policy negotiations. As the nature of potential GHG policies evolves and the regulatory backdrop of other energy, economic, and environmental policies emerges, improved understanding is needed of the importance of policy design and the role of the electric power sector under various policy alternatives. In particular, a better understanding is needed of the interplay between regulatory and market-based approaches to controlling emissions.

Approach
This project will develop comprehensive analyses of the cost of achieving GHG emission reductions specified in prominent climate change proposals. Research into cost-effective reductions will be undertaken to clarify the role of energy-related mitigation activities, as well as terrestrial carbon release associated with land use change and other offset opportunities, in an overall least-cost emission reduction portfolio. Some policy approaches will correspond more closely than others to a least-cost strategy. Analyses at the regional, national, and international levels will examine the effect of alternative approaches on carbon intensity, fuel and electricity prices, reliability of supply, household income, and other factors of interest to policymakers. The information, methods, and tools provided in this project represent key inputs for integrated assessment of the potential costs and benefits of climate change management proposals, helping to lay the foundation for sound policymaking. In particular, the US-REGEN model is being developed to provide state-of-the-art analytical capability for the integrated treatment of supply, demand, and transmission electric sector technologies at a regional level for the United States. Areas of focus in 2012 will include analysis of regulatory (for example, the Clean Energy Standard) as well as market-based policies and will explore the broadening role of state and regional policies domestically against a backdrop of international country commitments.

Impact
EPRI's climate policy research has played a critical role in informing international and domestic climate policy discussions for two decades. The program is well-positioned both to conduct essential research and to communicate key insights to public and private decision makers. This research will help ensure that

- essential elements of cost-effective policy measures are understood, providing members, the public, and policymakers with important insights on proposed regional, national, and international policies; basic education is more critical than ever given the interest in a complex mixture of regulatory and market-based policies;
- economic and technological concerns of the electric sector are addressed in policy debates, ensuring a substantial "seat at the table" for members; and
- participants gain vital knowledge and insights that facilitate strategic planning and enhance risk management activities within their organizations.

How to Apply Results
Project results are submitted to peer-reviewed journals for publication to ensure their robustness, credibility, and relevance. Key insights are distilled and communicated broadly to inform public policy processes. Equally important vehicles to ensure that member environmental staff, media/federal relations staff, and executives stay current on the research results include EPRI Climate Briefs and newsletters; attendance at EPRI advisory meetings and its annual Climate Seminar; up-to-date web content; and briefings for stakeholders, including policymakers, researchers, and press/media. Only through these means can members understand the constantly evolving key policy issues and position themselves at the leading edge of knowledge.
2012 Products

<table>
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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tr>
<td><strong>Assessment of Near-Term Costs of Domestic GHG Emission Reduction Proposals:</strong> This product will focus on implications of domestic climate policies, with emphasis on the value of market-based approaches versus less-flexible types of regulation. Policy impacts will be evaluated at the sectoral and regional levels exploring a variety of cost measures—for example, CO₂ price, electricity price, capital investment, and GDP impact.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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<tr>
<td><strong>Examination of International Policy Development:</strong> This product will continue to assess the implications of international climate policy proposals. In particular, it will examine the implications of alternative proposals for the United States, focusing on the role of abatement in emerging economies in meeting international climate goals. The implications of alternative burden sharing proposals will be examined.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
</tr>
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Future Year Products

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td><strong>Assessment of Near-Term Costs of Domestic GHG Emission Reduction Proposals:</strong> Future-year products will provide continually refined analysis of the evolving U.S. policy arena.</td>
<td>12/31/13</td>
<td>Peer Literature</td>
</tr>
<tr>
<td><strong>Examination of International Policy Development:</strong> Future-year products will provide continually refined analysis of the evolving international policy arena.</td>
<td>12/31/13</td>
<td>Peer Literature</td>
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P102.002 Integrated Assessment of Costs and Benefits of Climate Change Management Proposals (057737)

Key Research Question

Integrating economic policy cost information with estimates of market and nonmarket impacts is the central problem addressed by this project. The costs and environmental benefits of U.S. and international proposals for managing greenhouse gases need to be evaluated using a consistent and comprehensive approach, and analyses need to characterize the critical uncertainties effectively, so that stakeholders use objective information to arrive at economically and environmentally sound policy decisions.

Approach

This project will evaluate the environmental and economic implications of various proposed climate change policies using integrated assessment frameworks based on the latest results from economic, scientific, and technological research. This project will combine economic assessment with policy-relevant information about the interactions of technology and land-use decisions with the earth's carbon cycle, and the potential impact on key climate variables. Expanded emphasis will be placed on meaningful characterization of uncertainty. The resulting integrated assessments will be continuously refined and updated with new methods and information, taking into account changes in knowledge about climate-relevant emissions and processes as well as new proposals in the evolving policy debate. The continued development of EPRI's integrated assessment tool, the MERGE model, will be a key component of this project. Areas of focus in 2012 will include a more in-depth treatment of the interaction among aerosols, GHGs, and air quality policy, as well as more detail on the potential implications of bioenergy.
Impact

- Develops state-of-the-art, consistent, comprehensive frameworks for complex climate policy evaluations.
- Integrates credible and objective information on costs and benefits of climate change policies.
- Characterizes key uncertainties related to critical climate processes.
- Creates teams of experts able to quickly examine new information crucial to the policy debate, in a manner available nowhere else, by supporting continuous refinement of frameworks and policy assessments.

How to Apply Results

Project results are submitted to peer-reviewed journals for publication to ensure their robustness, credibility, and relevance. Key insights are distilled and communicated broadly to inform public policy processes. Equally important vehicles to ensure that member environmental staff, media/federal relations staff, and executives stay current on the research results include EPRI Climate Briefs and newsletters; attendance at EPRI advisory meetings and its annual Climate Seminar; up-to-date web content; briefings for stakeholders, including policymakers, researchers, and press/media; and peer-reviewed papers submitted to prestigious journals. Only through these means can members understand the constantly evolving key policy issues and position themselves at the leading edge of knowledge.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tr>
<td><strong>Enhanced and Updated Frameworks for Integrated Assessment of Policy Proposals:</strong> This product will incorporate the latest scientific, technological, and socioeconomic information into the world's leading integrated assessment models. Emphasis will be placed on better characterizing key uncertainties and their influence on policy formulation.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
</tr>
<tr>
<td><strong>Assessments of the Costs and Benefits of Policy Proposals:</strong> This product will apply integrated assessment frameworks to important research questions such as the implications for aerosol emissions and their interaction with local air pollution policies as well as the role of land-based activities in addressing global climate change.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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Future Year Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Enhanced and Updated Frameworks for Integrated Assessment of Policy Proposals:</strong> This product will continue to update leading integrated assessment frameworks to reflect new scientific, technological, and economic knowledge and to reflect the current and anticipated future climate debate.</td>
<td>12/31/13</td>
<td>Peer Literature</td>
</tr>
<tr>
<td><strong>Assessments of the Costs and Benefits of Policy Proposals:</strong> The updated integrated assessment models will be used to examine important emerging issues.</td>
<td>12/31/13</td>
<td>Peer Literature</td>
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</table>
P102.003 The Role of Technology in Managing Climate Change (067506)

Key Research Question

Technology is the key to making the transition to a low-carbon economy, both nationally and globally. An effective technology policy that speeds development and demonstration of technological advances can dramatically reduce the cost of meeting any future GHG reduction goal. For developing countries in particular—sources of rapidly increasing emissions—technology-based policy incentives are likely to be the most effective near-term approach. Moreover, there are potentially large benefits to developed countries of technology diffusion globally. Research is needed into the value of the availability, timing, and interactions of new climate-friendly technologies.

Approach

Using EPRI-sponsored models, this project will examine the role of technological advance in managing the costs of climate change policy compliance. Analysis will focus on individual electric sector technologies, including nuclear and carbon capture and sequestration (CCS), with added emphasis and detail on renewables, transmission, and end-use technologies. The value of advances in these technologies under various policy scenarios will be calculated, both nationally and internationally, with emphasis on how electricity competes with fossil fuels at the end use and on the role of electricity in decarbonizing other sectors of the economy. In addition, research will analyze what constitutes a prudent portfolio in the face of uncertain technology availability and costs, public acceptance, and future GHG limits. Both MERGE and EPRI’s new regional U.S. model will be used to assess the value of technology in a rigorous analytical framework. Efforts in 2012 are likely to focus on international deployment of advanced technology, in addition to examination of the roles of market and nonmarket approaches for catalyzing development and deployment of advanced technologies.

Impact

- Quantifies the value of technology under various climate policy scenarios
- Provides insights into technology advances and deployment
- Informs policymakers about ways to encourage technology innovation
- Highlights the potential benefits of technology diffusion abroad

How to Apply Results

Project results are submitted to peer-reviewed journals for publication to ensure their robustness, credibility, and relevance. Key insights are distilled and communicated broadly to inform public policy processes. Equally important vehicles to ensure that member environmental staff, media/federal relations staff, and executives stay current on the research results include EPRI Climate Briefs and newsletters; attendance at EPRI advisory meetings and its annual Climate Seminar; up-to-date web content; briefings for stakeholders, including policymakers, researchers, and press/media; and peer-reviewed papers submitted to prestigious journals. Only through these means can members and other stakeholders, including the public, understand the constantly evolving key policy issues and position themselves at the leading edge of knowledge.

2012 Products

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<tbody>
<tr>
<td>Analysis of the Role of Renewable Energy: Competing public studies envision a marginal,</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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<tr>
<td>modest, or dominant role for renewable energy in the future U.S. energy system. This</td>
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<td>product will examine a broad range of renewable technologies to gain insights into their</td>
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<td>potential role in the transition to a carbon-constrained energy system and how the</td>
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<td>optimal energy mix may vary across subnational regions. The work will contrast EPRI</td>
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<td>results with those of others, identifying critical assumptions that drive key</td>
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<td>differences.</td>
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</table>
Global Role of Climate Technology: This product will examine the role of alternative low-carbon technologies at the international level in managing the costs of coordinated emissions reduction efforts.

Analysis of the Sensitivity of Policy Cost to the Availability, Timing and Characteristics of Advanced Technologies: The cost of achieving significant emission reductions depends critically upon reducing the costs of low-emissions and nonemitting technologies. Some technologies will compete to provide reductions; other technologies will be complementary. This product will explore technology interactions in more detail, examining how alternative assumptions about a range of generation, transmission, storage, and end-use technologies affect future policy costs and strategies.

P102.004 Communications (067507)

Key Research Question

Effective communication of climate policy research results helps to inform stakeholder decisions. Climate policy is one of the most significant national and global environmental issues ever contemplated in terms of costs and implications for society. It is critical that decision makers have the best available information at their disposal.

Approach

EPRI climate research produces numerous insights for policymaking at a variety of levels. It is essential that these insights be effectively communicated to various stakeholder groups if the results are to help inform relevant policy discussions. Communication activities undertaken by EPRI staff include participation in international and domestic committees, workshops, and seminars; presentations, briefings, and testimony; and publication of Climate Briefs, newsletters, and papers in the peer-reviewed literature. It is critical that EPRI's research reach the broadest possible audience to help inform the overall policy debate. Key communication activities in 2012 will include the Annual EPRI Climate Seminar, enhancement and maintenance of the public climate web site, and participation of EPRI staff as lead authors in the IPCC Fifth Assessment Report.

Impact

- Improved understanding of critical design and implementation issues of cost-effective climate policy
- Improved understanding of the value of technology in managing the costs of climate policy
- Improved understanding of the results of integrated assessment of climate policy costs and benefits

How to Apply Results

Company environmental staff can use project information to inform company climate strategy, help identify and evaluate key investments in climate technology, and guide development of corporate policy positions. EPRI will facilitate broader use and awareness of the results by briefing key stakeholders, including policymakers and policy researchers; developing written materials for distribution; keeping the public web page current; presenting at meetings and seminars; and continuing service on various advisory panels.
## 2012 Products

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<td><strong>Communication Activities and Materials:</strong> Deliverables will include papers, research summaries, webcasts, the program web site, briefings, and presentations, supplementing EPRI reports and peer-reviewed literature created by other projects in the program.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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## Future Year Products

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<td>12/31/13</td>
<td>Technical Resource</td>
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</table>
Environmental Compliance Strategy Support (072068)

Background, Objectives, and New Learnings

Coal today provides over half of U.S. electricity. However, evolving environmental regulation of sulfur dioxide, nitrogen oxides, and mercury combined with possibility of regional and national climate legislation, possible new regulations on cooling technology, and a reconsideration of ash management regulations creates great uncertainty for existing and potential new coal assets. The impacts of these regulations must be evaluated against the backdrop of changing electricity markets. Electricity markets may be fundamentally changed by possible climate policy, whether market based or technology-forcing, and will almost certainly be impacted by significant additions of renewable generation in some regions. Increased abundance of natural gas may be another game-changer.

As companies consider future investments to comply with evolving environmental regulations, the answers may be clear for some older and relatively small units and they may be equally clear for newer and larger units. However for a large fraction of units that fall in the middle of the age-size distribution, the answers will be unclear and will depend critically on how public policy, regulations, and the actions of near competitors evolve to conditions in regional power markets. The basic question becomes whether the cost of investments to keep the unit running can be justified by the future, uncertain value of its output.

While the engineering and technology assessment necessary to assess the retrofit cost is difficult enough, the owner must also assess the unit’s role in the future power market and how that role changes with climate policy or swings in natural gas prices, how it changes with the introduction of new renewable generation, and how it changes as new environmental policies for air, water and ash management lead to the shutdown or curtailment of competing units.

Tens of billions of dollars of value in existing assets are at stake. Having a clear understanding of both the investment worthiness of their existing fleets and the potential value of new generation is needed to help companies make better decisions, and communicate them to stakeholders.

This project is designed to help utilities quantify the potential value of investments in retrofits or in new generation in this evolving world. It intends to give the generation owner a market-based assessment of how much investment its retrofit candidates can support, measured in dollars per kilowatt, and how robust these investments may be under a wide range of plausible futures.

Collectively, the retrofit-retire decisions for the electric sector reflect a potential impact of 100s of billions of dollars for electric customers and consumers of goods and services. This project may lead to improved decision making to help assure that this investment is well spent. Generic (non-proprietary) and general methodological insights from the individual-company analyses conducted through by this project will be communicated through an EPRI Technical Update.

Project Approach and Summary

Project participants identify for detailed study a set of candidate units, possible retrofit investment options, and a range of energy and environmental policy futures. Through past and ongoing Greenhouse Gas Reduction Options program research, EPRI has developed a broad set of analysis tools that greatly increase EPRI’s capabilities to analyze retrofit-retire decisions in a market context. Regional models of the U.S. and regional electricity markets developed as part of the Prism 2.0 project add to this capability. In this project EPRI will adapt and apply these tools to:

- evaluate how much in total one might be willing to invest in each generating unit for all the environmental controls that potentially may be required,
• examine the robustness of the specific investment options of interest across the scenarios, and
• examine the influence of timing of policies and uncertainties on the value of these investments.

The analysis will provide a detailed, bottom-up simulation of the regional power market that calculates the annual distribution of market prices, CO₂ emissions and the cash flows ascribable to each generating unit in the stack.

Benefits

This project is designed to help utilities quantify the potential value of investments in retrofits or in new generation in this evolving world. It intends to give the generation owner a market-based assessment of how much investment its retrofit candidates can support, measured in dollars per kilowatt, and how robust these investments may be under a wide range of plausible futures.

Collectively, the retrofit-retire decisions for the electric sector reflect a potential impact of 100s of billions of dollars for electric customers and consumers of goods and services. This project may lead to improved decision making to help assure that this investment is well spent. Generic (non-proprietary) and general methodological insights from the individual-company analyses conducted through by this project will be communicated through an EPRI Technical Update.

This analysis provides two features critical to accurate assessment of the value of retrofit investments.

• Market analyses extending to 2050 (encompassing a full lifecycle for new investment) are needed to fully capture the long-term effects of climate and clean energy policies on the recovery of retrofit investments and the addition and mix of new generation.
• Integrated regional market analysis is critical to quantifying the “survivor value” for units that remain in service (after retrofits) following a wave of retirements. These retirements have a direct impact on power prices and thus cash flows underlying retrofit investment worthiness.

Both of these features are outside the scope of most IRP analysis tools, yet are integral to the EPRI modeling approach. Including these issues is critical to fully capturing the value, and risks, to retrofit investments.
Regional Deployment and Implications of Renewables (072069)

Background, Objectives, and New Learnings

Policies to deploy renewable energy are spreading rapidly across the United States and around the world. Investment tax credits, production tax credits, many variants of renewable portfolio standards, clean electricity standards, feed-in tariffs, and other mechanisms have been proposed or are in-place. In the United States, 29 states and the District of Columbia have adopted renewable incentives. California is now targeting 33% of electricity from renewable generation by 2020. The federal government also has described the general outlines of a Clean Electricity Standard that would require 80% of electricity to be generated by "clean" technologies by 2035 and either market- or regulation-based climate policies could further incentivize renewable deployment. Impacts on costs, electricity rates and environmental emissions, and compliance options are key research questions to be examined. Each state and region of the United States has unique resources, existing generation, transmission and distribution assets, load patterns, and other considerations that will affect strategy for complying with these regulations and considering the economic incentives.

Because of its intermittent nature, location dependence, low energy density and capital intensiveness, widespread deployment of renewable energy can create many challenges for electric companies. Variability coupled with low marginal cost of operation will lead to increased cycling of dispatchable assets and can provide challenges to the electricity market designs (as evidenced in Europe). Wind resources, transmission, electricity storage and natural gas generation are intertwined in ways we are just beginning to understand.

This project will build upon data and models developed and applied as part of EPRI’s US regional model development to examine the economic potential of renewable resources on a state-by-state basis, to understand broad-scale regional issues for tying in these resources, and examining interactions with other generation, energy storage and demand under a variety of possible future policies.

Learning from this project may inform company compliance strategies as well as provide valuable input to policymakers as they craft future renewable, energy and environmental policies. Key insights will be published as a technical update.

Project Approach and Summary

Project participants will work closely with EPRI staff to develop and review regional analyses of renewable resources, high-level integration issues, and policy implications. This work will provide the public as well as electric power companies with information associated with making the most economically sound choices for renewable energy on a regional basis. Basic analyses can be conducted if there is only one funder in a region; much more detailed analyses can be conducted when there are multiple funders in a region. Key elements include:

- **Resource evaluation.** EPRI will work with funders to explore 14 years of hourly wind resource data at the state level in order to get a better understanding of wind potential and its correlation with load. A similar investigation will be made of solar opportunities, both photovoltaic technologies and concentrating solar power, where appropriate. Biomass supplies under different energy policies and other renewable resources will be investigated. The biomass resource assessments will explicitly recognize the cross-sector impacts on agricultural and forestry markets through land use modeling.

- **Analysis.** Analyses will be conducted to examine the implications of a range of energy and environmental policies as well as to understand the implications of key uncertainties, e.g., natural gas price. The tools utilized will depend upon the questions specific to the regions, but will likely include a dynamic version of EPRI’s regional modeling framework which simulates the economy though 2050, a one-year version of the model which allows examination of 8760 hours of resource supply and load data (allowing for examination of energy storage as an option for dealing with intermittent generation), and possibly a more detailed, unit commitment model.
These analyses can help companies develop renewable compliance strategies, anticipate market and asset value impacts as well as operational challenges (e.g., generation cycling) from a rapid influx of renewable generation in their region, and communicate critical insights on the opportunities and costs to legislators, regulators and the public.

Benefits

Companies and the public at large are expected to gain a better understanding of regional renewable resources and deployment implications under a range of renewable, energy and environmental policies. These policies can affect not only investments in renewable generation and renewable compliance strategy, but also can impact investment decisions for both upgrades of existing generation and new, non-renewable generation. Key insights from analyses can help inform policymakers and the general public.
Greenhouse Gas Reduction Options - Program 103

Program Overview

Program Description

The on-again, off-again progress of climate policy at international, national, and state levels has created increased uncertainty for the electricity sector. Despite strong support for climate bills in the U.S. House of Representatives and Senate in 2008–2009, a national market-based climate policy now seems unlikely in the immediate future, and there is uncertainty over the U.S. Environmental Protection Agency’s (EPA’s) potential approach to managing greenhouse gases (GHG) under the Clean Air Act. While some state and regional efforts to regulate GHG emissions have taken a step back, California’s Global Warming Solutions Act is now coming into force, imposing a mixed approach of cap-and-trade with multiple layers of nonmarket policies, and clean energy policies at state and federal levels add another source of uncertainty. This heightened policy-based uncertainty comes at a particularly inopportune moment for the industry as it faces potentially massive environmental retrofit requirements for an aging coal fleet. In addition, while natural gas prices have collapsed from recent historic highs, the age of natural gas price volatility is not over.

Despite uncertainty about the timing and form of climate policy, few observers believe that the climate issue has been settled and that electric sector planners and investors can assume GHG emissions will no longer face potential regulation. The current pause in the federal policymaking process provides an opportunity to build a stronger understanding by the public and policymakers of the strengths and weaknesses of alternative approaches to GHG regulation (many elements of which were only cursorily examined in 2009–2010 as policies were debated), to develop the technologies needed to make reductions more cost-effective, and to develop the underpinning of regulatory systems (for example, emission offsets) that will prove critical to gaining real emission reductions and controlling costs when federal policies are introduced.

In this uncertain atmosphere, the Electric Power Research Institute’s (EPRI) Greenhouse Gas Reduction Options program provides public- and private-sector decision makers with vital insights regarding the costs, availability, performance, and potential risks of GHG emission reduction and mitigation options. The program provides investment strategies for expanding these options in the future and insights on how to integrate GHG policy risk management and multipollutant compliance into corporate business strategies. This information helps electric sector companies develop coherent corporate climate strategies and provides decision makers with information to create and implement cost-effective, environmentally sound public policies in a complex and multifaceted regulatory environment.

Activities in the Greenhouse Gas Reduction Options program (P103) described here complement activities in the Global Climate Policy Costs and Benefits program (P102). P103 examines energy, environment, and climate issues from a utility-level perspective, often considering choices, implications, and actions down to the individual generating unit level. In addition, P103 research examines key details of climate policy—for example, alternative accounting procedures for GHG emissions offsets or what buyer liability might mean for a trading scheme—and has often provided a neutral forum for stakeholder discussions of key issues. P103 results are typically communicated via workshops and EPRI technical reports, with less emphasis on publishing results in peer-reviewed journals. P102 research takes a complementary view, providing critical insights into global, national, and regional climate policy choices—choices that define the context in which companies will have to make decisions. P102 provides ongoing support of modeling frameworks internally and at the Massachusetts Institute of Technology and Battelle Pacific Northwest National Laboratory in order to inform policy discussions. P102 staff are active participants in the Intergovernmental Panel on Climate Change (IPCC) and in National Academy of Science panels, and almost all of P102’s results are published in peer-reviewed journals. Together, the two programs provide an integrated, consistent view of energy and climate policies and company strategies from a variety of vantage points.
Research Value

Policymakers and utility personnel need to understand the implications of climate policy implementation choices (such as program scope, use of market mechanisms, and offsets) and potential compliance costs. They need to understand how possible overlaps in regional and national policy initiatives, and in energy policies mandating renewables and energy efficiency and promoting nuclear and advanced fossil generation, complement each other or lead to unintended consequences. They also need to understand all of these forces within a broader environmental and energy regulatory context. Through its GHG reduction options research, EPRI helps the industry and the public understand the costs and risks associated with a low-carbon future; make strategic generation, delivery, and end-use technology choices; and communicate these insights to policymakers and state regulators. With this research, power companies and the public may see

- more-efficient (and thereby less expensive) policy designs due to better effectiveness of the user community in informing the policy development process;
- lower compliance costs and less risky business strategies due to better understanding of potential impacts of climate policy on power markets and incentives to add, modify, or retire generation; and
- a higher probability that cost-effective emission reduction options, such as GHG offsets, will be available to reduce compliance costs.

Approach

The program provides improved analytical approaches to support strategic decisions and consideration of generation investments and emission reduction options. It produces tools and methodologies that help companies develop least-cost approaches to achieving voluntary and mandatory GHG emissions reduction targets. The program informs the public policy process by communicating research results to the broadest possible audience through issue briefs; newsletters; congressional testimony; technical workshops; briefings for stakeholders, policymakers, researchers, and the press/media; and peer-reviewed publications. This program delivers

- a greater understanding of how climate policy will fundamentally change electric sector economics and affect power markets,
- opportunities to inform evolving climate policies by helping companies understand subtle nuances of climate policy design and their impact on utility asset owners and customers,
- key insights into robust compliance strategies, and
- increased understanding of how detailed policy design alternatives, impacts on power markets, the role of advanced low-emission technologies, and opportunities for GHG offsets can have tremendous value in forging robust corporate business and compliance strategies in a turbulent environment.

Accomplishments

Climate policy designs for achieving an environmental goal can vary in cost by trillions of dollars, and climate policy can significantly affect returns on existing capital and on new corporate investments. Sound analyses and clear communication are critical to creating effective, efficient policies and effective corporate strategies. Program accomplishments include the following:

- Expanded the Global Climate Policy Design Forum Series to inform company, Congressional, and administration discussions on key domestic policy choices. Recent workshops have focused on emission offset policy.
- Helped companies develop and publicly communicate key elements of their corporate climate strategies.
- Developed and applied frameworks for helping companies evaluate specific generation and emissions reduction investments.
- Launched a comprehensive effort to re-evaluate the potential international and domestic supplies of GHG emission offsets.
- Examined and communicated the implications of a CO₂ price in a regional electricity market.
Current Year Activities

Program R&D for 2012 will focus on

- analyses examining GHG offset mechanisms, particularly technical challenges in their implementation, design issues affecting environmental and political feasibility, strategies for companies to acquire offsets, and estimates of their economic value;
- analyses of detailed implementation of climate policy choices, such as the interplay between market and regulatory/technology-forcing approaches to climate and energy policy;
- frameworks to incorporate long-term power market and GHG regulatory impacts into corporate business and compliance strategies;
- assessment of the ongoing climate policy experience in California, the European Union, and other countries and regions to discern key lessons for policy design and company compliance strategies; and
- frequent domestic and international climate policy workshops and policy forums.

Estimated 2012 Program Funding

$3.0M

Program Manager

Victor Niemeyer, 650-855-2262, niemeyer@epri.com

Summary of Projects

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P103.001</td>
<td>Investigate GHG Offset Program Design and Economics</td>
<td>This project examines GHG offset mechanisms, particularly technical challenges related to their implementation, design issues affecting environmental and political feasibility, and economic value. This information will help electric utilities understand program design alternatives and tradeoffs, and communicate this understanding to policymakers and stakeholders.</td>
</tr>
<tr>
<td>P103.002</td>
<td>Investigate Use of Market and Nonmarket Mechanisms in Climate Policy Design</td>
<td>This project provides analyses of market and nonmarket mechanisms for controlling GHG emissions and meeting other clean energy goals, and the possible interactions from a combination of the two approaches. This work will improve understanding of these issues and help utilities communicate their implications to policymakers and stakeholders.</td>
</tr>
<tr>
<td>P103.003</td>
<td>Methods to Assess GHG Policy Impacts on Business Strategy and Compliance</td>
<td>This project will help electric utility decision makers understand the implications of climate and other clean energy policies, both market and nonmarket, for their companies and incorporate policy uncertainty into their business strategies, investment decisions, and compliance choices.</td>
</tr>
<tr>
<td>P103.004</td>
<td>Assessing the Experience of International, Regional, and State GHG Policies</td>
<td>This project will provide insights into experience to date with policies managing GHG emissions from the electric and energy sectors throughout the world. This perspective will help utilities be better informed participants in GHG policy debates and understand implications for their own business organization decisions.</td>
</tr>
<tr>
<td>P103.005</td>
<td>Communications</td>
<td>This project helps members communicate program results on climate policy complexities to diverse stakeholders through workshops, issue summary documents, and other communication channels.</td>
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P103.001 Investigate GHG Offset Program Design and Economics (057734)

Key Research Question

Offsets are emission reductions, sequestration, or avoidance created by projects and activities at emission sources and, in economic sectors, not covered by a GHG emissions trading program’s fixed cap. By encouraging emission reductions where they can be achieved most cost-effectively, offsets can play a critical role in reducing compliance costs for regulated entities and the overall economy if a large-scale CO₂ cap-and-trade program is implemented to reduce national GHG emissions.

Offsets allow entities like electric utilities and other covered sectors in any future national GHG cap-and-trade program to substitute lower-cost GHG emissions reductions implemented outside of a U.S. GHG regulatory emissions cap for more-expensive internal emissions reductions under the domestic cap.

According to analyses by EPA, the Energy Information Administration, and the Congressional Budget Office (CBO), the potential availability of offsets is the single variable that has the greatest degree of impact on expected future CO₂ prices under the 2009 Waxman-Markey legislative proposal (HR2454/ACESA). The CBO concluded that CO₂ allowance prices can be expected to be more than three times more expensive by 2030 if no offsets are available and that “…The cost savings to the economy generated by offsets could be substantial….between 2012 and 2050 average annual savings from offsets could be about 70 percent under ACESA.” [1]

Internationally, the role of offsets also is hotly debated and is a key element of emerging climate policy for the post-Kyoto period. Currently, the nature and potential role of new kinds of offsets, such as sectoral offsets and offset credits from Reduced Emissions from Deforestation and Degradation (REDD), as well as the ongoing discussions about the future role of an improved and reformed Clean Development Mechanism (CDM) program, are the center of attention in international negotiations. EPRI has a number of ongoing supplemental projects focused in these specific areas that provide valuable insights and information, which are then incorporated back into EPRI’s offsets research.

The design of a large-scale, cost-effective offsets program that can maintain a high degree of environmental integrity is a challenging endeavor. A myriad of policy-related questions must be addressed, including the design of basic institutions necessary to administer a large-scale and environmentally effective offsets program. Key questions to be addressed include the following:

- What sources of offsets (domestically or internationally) may count as compliance instruments in a future CO₂ mitigation program
- What specific types of projects and programs may be allowed to generate offsets
- How will the “additionality” of a project be determined
- Will there be limits to the use of offsets for compliance purposes, and if so, how will these limits be designed
- How are offset projects approved, registered, and ultimately issued GHG offset credits
- How are offset methodologies established, and who oversees their development and implementation

These and many other pertinent questions will need to be addressed if a large-scale federal or regional offsets program is to be implemented in the near term to help contain costs in evolving regional and national CO₂ cap-and-trade programs.

It is also important to understand how climate policy design choices impact the cost and availability of GHG offsets. Inclusion of international offsets in U.S. climate policy could allow access to potentially large sources of international offsets but could also inadvertently link the U.S. carbon market to the economies of other nations. The sectoral coverage of any economywide cap-and-trade program that may evolve in the United States defines which domestic sectors are potentially eligible to generate offsets by virtue of which sectors are excluded from the cap.
Approach

This project examines GHG offset mechanisms, particularly technical challenges in their implementation, design issues affecting environmental and political feasibility, and economic value. In a future cap-and-trade GHG policy, offsets could have tremendous benefit in lowering compliance costs, but these programs are complex and the benefits highly sensitive to nuances of program design. This information will help electric companies to better understand program design alternatives, to lay the framework for workable systems, and to communicate with policymakers and stakeholders. In 2012, the project will examine how key policy design choices impact the potential benefits of offset programs, and policy dialogues will focus on the policy and institutional development needed to make offsets viable when market-based policies are enacted.

Impact

- Examines emerging experience with climate policy and offsets programs evolving across the United States and in other countries to inform new policy implementation; identifies important lessons from early trading system experiences
- Provides clear communication regarding implications of different rules and restrictions on offsets and trading
- Develops and applies models to quantify implications of different policy implementation choices
- Evaluates and analyzes different approaches to creating GHG emissions offsets and provides insights about the expected cost and potential availability of offsets
- Conducts basic research into innovative offset ideas and helps to refine methodologies for evaluating offset projects and estimating availability
- Contributes to development of protocols designed to quantify, measure, monitor, and verify GHG emissions offsets, and examines implications of different rules for crediting offset projects

How to Apply Results

Company environmental staff can use this project's information to inform their company's climate strategy, help identify and evaluate possible near-term GHG emission reduction investments, and guide development of corporate policy positions. EPRI researchers will facilitate broader use and awareness of the results by briefing key stakeholders, including policymakers, other researchers, and the public; developing materials for the trade press/media; keeping EPRI's public website current; presenting at meetings/seminars; and continuing service on various advisory panels.

2012 Products

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<tr>
<td>Analysis of Key Greenhouse Gas Emissions Offset Issues: With inputs from program members, EPRI will examine how key policy design choices impact the potential benefits of offset programs and will organize policy dialogues that will focus on the policy and institutional development needed to make offsets viable when market-based policies are enacted.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Analysis of Key Greenhouse Gas Emissions Offset Issues</strong>: Future deliverables will be determined annually based on evolving climate policies. Research will continue on the general range of subjects related to GHG offsets. Analytical tools will be developed and enhanced to allow quantitative analyses of emerging policy proposals.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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**P103.002 Investigate Use of Market and Nonmarket Mechanisms in Climate Policy Design (070653)**

**Key Research Question**

Economically efficient climate policy approaches such as global emissions trading can cost trillions of dollars less than more-prescriptive regulatory policies to achieve the same emissions levels. However, U.S. and international climate policy is at a particularly uncertain point. The end of the Kyoto framework period is rapidly approaching, and recent United Nations Climate Change Conference meetings have not developed a clear path beyond that period. At the U.S. federal level, an economywide cap-and-trade policy appears to be off the table for now; policymakers are exhibiting distrust and confusion over use of market mechanisms; a court order is forcing EPA to try to regulate CO₂ emissions through the Clean Air Act; and there is tremendous interest in encouraging the penetration of renewable generation technologies and taking other steps to incentivize lower-emitting energy sources. In addition, states are considering regulatory approaches that they view as needed complements to possible future federal market-based systems. A patchwork of market and nonmarket energy and environmental policies has the potential to be unnecessarily costly, inefficient, and ultimately, ineffective. Understanding and communicating the potential complementary and competitive interactions of overlapping policies can help avoid inefficient policies and unintended consequences.

**Approach**

This project provides analyses of market and nonmarket mechanisms for controlling GHG emissions and meeting other clean energy goals, and examines the possible interactions from a combination of the two approaches. This work will improve understanding of these issues and help utilities communicate their implications to policymakers and stakeholders. In 2012, the project will focus on communicating historic examples illustrating the strengths and weaknesses of market and nonmarket policy designs, with a focus on nonmarket policies currently under discussion (for example, New Source Performance Standards, Clean Energy Standard, California regulations).

**Impact**

- Develops and applies models to quantify implications of different market and nonmarket climate policy implementation choices
- Develops and applies models to quantify implications of clean-energy policy implementation choices and assess their interactions with climate policy alternatives
- Examines ongoing experience with climate policy across the United States and other countries to understand policy choices and their implications
- Provides clear communication regarding implications of different rules and restrictions on trading and technology-driven regulatory mandates
How to Apply Results

Company environmental staff can use the information to inform their company’s climate strategy, help identify and evaluate possible near-term GHG emission reduction investments, and guide development of corporate policy positions. EPRI researchers will facilitate broader use and awareness of the results by briefing key stakeholders, including policymakers, other researchers, and the public; developing materials for the trade press/media; keeping EPRI’s public website current; presenting at meetings/seminars; and continuing service on various advisory panels.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Analysis of Market and Nonmarket Mechanisms in Climate Policy Design: With input from program advisors, results will be delivered primarily through a technical report on opportunities and challenges of using a mix of market and nonmarket mechanisms for controlling GHG emissions and meeting other clean energy goals. Insights will also be shared with program members and other stakeholders through presentations and workshops.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Analysis of Market and Nonmarket Mechanisms in Climate Policy Design: Future deliverables will be determined annually based on evolving climate policies. Research will continue on the general range of subjects in emissions trading and nonmarket policies. Analytical tools will be developed and enhanced to allow quantitative analyses of emerging policy proposals.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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P103.003 Methods to Assess GHG Policy Impacts on Business Strategy and Compliance (047425)

Key Research Question

Any policy seeking to reduce CO₂ emissions below historical levels will have a dramatic impact on electric power prices, cash flows to generating assets, and incentives for investments in new and existing generation. The resulting electricity market is likely to be fundamentally different from today’s, driven in particular by a large influx of nondispatchable generation. With few options to achieve substantial short-term emission reductions, and expensive, technologically or institutionally uncertain long-term options, the costs and reliability impacts could be problematic. A binding emissions cap with a substantial share of auctioned allowances could expose the electric sector to over $100 billion per year in CO₂ costs in a market that is likely to be highly volatile. Electric utility decision makers will need new methods and analytical frameworks to navigate this sea change in their compliance and business environment.

Approach

This project will help electric utility decision makers understand the implications of climate and other clean energy policies, both market and nonmarket, for their companies and incorporate policy uncertainty into their business strategies, investment decisions, and compliance choices. In 2012, the project will focus on implications of nonmarket energy and environmental policies on utility investment and technology strategies.
Impact

- Helps companies assess climate policy risks and opportunities and develop strategies to manage both
- Assesses implications for companies of the overlap of climate policy with policies promoting renewable energy and conservation
- Provides methods for evaluating capital investments in existing generation given policy and other uncertainties
- Provides methods for comparing emission reduction investments—from on-system options to emissions offsets—on a consistent basis
- Helps companies communicate the implications of climate policy to stakeholders

How to Apply Results

Company environmental and planning staff can learn from reports, presentations, and workshops about how to consider climate policy uncertainty for planning and operational activities. Key insights may be communicated to a broader stakeholder audience in order to widen understanding of the drivers and dynamics of electric company decision making.

2012 Products

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<tr>
<td>Development of Methods to Assess GHG Policy Impacts on Business Strategy and Compliance: Project results will be delivered primarily through a technical report providing methodological insights and results concerning the impact of stringent climate and clean energy policies on power markets, and on the consistent assessment of compliance options. Insights will be shared with program members and other stakeholders through presentations and workshops.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<tbody>
<tr>
<td>Development of Methods to Assess GHG Policy Impacts on Business Strategy and Compliance: Future deliverables will depend, in part, on whether climate legislation in the United States has been passed or is imminent. There is likely to be an ongoing need to understand new generation choices, given continuing uncertainty about climate policy, fuel prices, capital costs, and public acceptance of technology.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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P103.004 Assessing the Experience of International, Regional, and State GHG Policies (067509)

Key Research Question

The many international, regional, and state efforts to institute climate and clean energy policies constitute a laboratory of parallel experiments. Some of these policies are already in force, regulations are being developed for others, and some are under active consideration and may become law. What have been the magnitude and nature of the economic consequences, including relocation of industry? How have the nuances of policy designs impacted electric utilities and their customers? How have companies organized themselves to comply with policies and to identify new opportunities those policies may create? Understanding the successes and failures of these policies can help inform policy discussions of new proposals in the United States and elsewhere. Electric power companies and their customers are key stakeholders in these debates, and thus they have a
strong need to understand the efficacy and consequences of policy proposals and to effectively communicate that understanding in the policymaking process.

**Approach**

This project will provide insights into experience to date with policies managing GHG emissions from the electric and energy sectors throughout the world. This perspective will help utilities be better informed participants in GHG policy debates and understand implications for their own business organization decisions. In 2012, this project will likely focus on synthesizing lessons learned to date from the EU trading scheme (in terms of both policy design and company compliance strategies) and from state and regional programs in the United States.

**Impact**

- Helps clarify and communicate international and regional-level climate policy impacts on national and global emissions given the opportunities for relocation of economic activity and trade
- Helps assess the potential effects of climate policy on electricity markets and economic activity
- Increases capability to support electric utilities that are participating in policymaking processes

**How to Apply Results**

Company environmental staff can use the information to inform their company’s climate strategy, help identify and evaluate possible near-term GHG emission reduction investments, and guide development of corporate policy positions. EPRI researchers will facilitate broader use and awareness of the results by briefing key stakeholders, including policymakers, other researchers, and the public; developing materials for the trade press/media; keeping EPRI’s public website current; presenting at meetings/seminars; and continuing service on various advisory panels.

**2012 Products**

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<tr>
<td>Assessing the Experience of International, Regional and State GHG Policies: With input from Program Advisors, this project will synthesize lessons learned to date from the EU trading scheme (both in terms of policy design and company compliance strategies) and from state and regional programs in the US. Insights will be shared with program members and other stakeholders through presentations and workshops.</td>
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<td>Technical Resource</td>
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**Future Year Products**

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<tr>
<td>Assessing the Experience of International, Regional and State GHG Policies: Future deliverables will be determined in consultation with members. Topics will depend, in part, on the course of climate and energy policies at state and regional levels in the U.S. and in other countries.</td>
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**P103.005 Communications (067510)**

**Key Research Question**

EPRI climate research produces numerous insights for policymaking at a variety of levels. It is essential that these insights be effectively communicated to various stakeholder groups if the results are to help inform relevant policy discussions. Much of this material is rooted in economic theory or based on implementations of climate policy in distant international venues, making it difficult to access and interpret.
Approach
This project helps members communicate program results on climate policy complexities to diverse stakeholders through workshops, issue summary documents, and other communication channels. In 2012, this project will continue to support a series of policy dialogues, webcasts for members, participation in external committees, the enhancement and maintenance of the Global Climate public website, and other communication efforts.

Impact
- Improved understanding of issues critical to the design and implementation of cost-effective climate policy
- Better understanding of how climate policy affects electric power markets and the implications for investment and operating decisions
- Better understanding of the potential opportunities and challenges for electric companies in meeting compliance goals
- Increased effectiveness in communicating the important details of climate policy design and critical tradeoffs to investors, electric company customers, policymakers, and other stakeholders

How to Apply Results
Company environmental staff can use the information to inform company climate strategy, help identify and evaluate possible near-term GHG emission reduction investments, and guide development of corporate policy positions. EPRI researchers will facilitate broader use and awareness of the results by briefing key stakeholders, including policymakers and policy researchers; developing materials for the trade press/media; keeping the program’s public website current; presenting at meetings/seminars; and continuing service on various advisory panels.

2012 Products

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<tr>
<td><strong>Communication Activities and Materials:</strong> With input from program advisors, deliverables will be determined based on evolving climate and energy policies. Topics, modes of communication, and key audiences will depend, in part, on the status of climate negotiations, legislation, regulation, and implementation.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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Future Year Products

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<tr>
<td><strong>Communication Activities and Materials:</strong> Future deliverables will be determined in consultation with members. Topics, modes of communication, and key audiences will depend, in part, on the status of climate policy discussions and implementation.</td>
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<td>Technical Resource</td>
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Supplemental Projects

Development of New GHG Offsets (072071)

Background, Objectives, and New Learnings

This project will facilitate development of greenhouse gas (GHG) emissions offsets associated with activities to enhance management of biomass vegetation growing on high-voltage electricity transmission system rights of way (ROW) owned or managed by electric companies.

While climate policy debates continue, analysts agree that identifying large-scale, cost-effective GHG emissions reductions opportunities is critical to containing the expected economic costs of implementing climate change mitigation programs. Managing vegetation on rights of way to maintain and increase biomass and carbon stocks is one promising opportunity to reduce emissions and create offsets. These offsets may help companies to comply with future state, regional and national GHG emission reduction policies.

Currently, many electric companies seek to comply with transmission system vegetation management regulations imposed by the North American Electricity Reliability Corporation (NERC) by removing virtually all vegetation growing on transmission system rights of way. This approach is expensive for electric companies to implement, reduces species habitat and is a source of GHG emissions.

By committing to maintain or increase the amount of biomass vegetation and associated carbon stocks growing on transmission ROWs, electric companies potentially can reduce their ROW management costs, enhance wildlife habitat, and create valuable GHG emissions offsets, while maintaining critical system reliability. This may be the case whether an electric company owns its ROWs or has long-term management easements on its ROWs.

This project builds on the experience gained in EPRI Program 103’s successful efforts to demonstrate new potential offset activities (e.g., reducing nitrous oxide (N$_2$O) emissions in agricultural crop production), and upon extensive research in Program 51 to develop cost-effective, environmentally beneficial approaches to implementing Integrated Vegetation Management (IVM) programs on electric company transmission system rights of way.

Project Approach and Summary

This project is designed to assess the overall technical feasibility of developing GHG emissions offsets on electric company transmission ROWs by implementing enhanced Integrated Vegetation Management. To accomplish this goal, the project incorporates three key components:

1. **Assess the potential to utilize existing GHG emission offsets accounting methodologies and protocols**, such as those previously developed by the American Carbon Registry (ACR), the Climate Action Reserve (CAR) and the Verified Carbon Standard (VCS), to quantify the potential GHG emission offsets that may be granted to electric companies in exchange for implementing enhanced IVM approaches on their transmission system ROWs. The major existing carbon offsets accounting protocols and methodologies in use today in the U.S. allow an owner or long-term manager of land to generate GHG emissions offsets based on a forest’s ability both to emit and sequester carbon dioxide (CO$_2$). Offsets derived from preventing CO$_2$ emissions associated with tree cutting and removal of biomass vegetation are referred to as “stocking retention” or “avoided deforestation” offsets and are measured in terms of standing timber or biomass relative to a standard “baseline.” Offsets derived from increasing the amount of carbon stored in trees or other living biomass as compared to an appropriate baseline are referred to as “growth” offsets and are measured in terms of annual growth of the forest and associated biomass vegetation.
2. Evaluate the potential benefits, risks and financial costs to develop a new, customized offsets accounting protocol specifically designed to be used by electric companies to create GHG offsets by implementing IVM on transmission ROWs. This effort will address several initial steps in creating a new offset protocol including: defining the types of activities that may qualify to create offsets, defining associated project “baselines,” and evaluating different approaches that may be used to assess the “additionality” of a proposed transmission ROW offsets project.

3. Utilize Geographic Information System (GIS) analysis tools to estimate the tons of offsets that could be created by implementing IVM on transmission ROWs.

If sufficient resources are available, this project may also evaluate the feasibility of developing GHG emissions offsets on distribution system rights of way.

Benefits

It is expensive for electric companies to manage vegetation growing on transmission ROWs. For example, a mid-sized U.S. electric company could spend as much as $10-$20 million annually to manage their ROWs in compliance with existing legal requirements and to avoid system outages inadvertently caused by in-growth of trees and/or trees falling into the wire security zone. Based on the results of this project, electric companies may be able to reduce the annual cost of managing vegetation growing on their ROWs by using less expensive management approaches and by developing GHG emissions offsets that can be sold to others in the market, and/or used by the company to comply with future GHG reduction obligations. By studying the risks of vegetation and its management in ROWs, the risk of electricity outages and their economic impact to the public may be greatly reduced.
Coal Combustion Products - Environmental Issues - Program 49

Program Overview

Program Description

Significant uncertainty exists regarding management of coal combustion products (CCPs), due largely to the U.S. Environmental Protection Agency’s (EPA’s) newly proposed options governing CCP disposal. The new proposal includes options ranging from hazardous waste designation and complete phaseout of wet management, to nonhazardous waste regulations similar to those for municipal solid waste. The outcome will significantly affect disposal options and costs, as well as CCP use in products and land applications. This regulatory process, and subsequent implementation and compliance activities, will likely be a key driver for CCP research for the next 5 to 10 years. In addition, increased air emissions controls and new fuel blends change CCP characteristics, which can affect both disposal and use, and increase CCP volumes, while environmental standards for trace constituents such as arsenic and chromium continue to trend downward. This changing landscape highlights the need for new and updated information on CCP composition and leaching characteristics, environmentally protective management methods, groundwater protection and remediation requirements, and risk assessment data for CCP storage, disposal, and use. As older power plants reach the end of their useful lives and their sites are considered for repowering or other uses, systematic assessment of their decommissioning will be required.

The CCP Environmental Issues program provides scientific data, engineering knowledge, restoration methods, and other tools for cost-effective soil and groundwater protection associated with fossil fuel–fired power plants and CCP storage, disposal, and use. Research currently focuses on the effects on CCP management options of new control technologies for mercury and other hazardous air pollutants (HAPs), sulfur oxides, and nitrogen oxides; disposal regulations being developed by EPA; ash pond management and closure; new leach test methodologies; groundwater remediation; environmental performance of CCP land applications; and health and ecologic risk assessment.

Research Value

Program research provides fundamental data on environmental management of CCPs. Collaborative efforts with other organizations, including EPA and the U.S. Department of Agriculture (USDA), specifically address pressing needs with respect to CCP disposal and new large-volume uses for increased quantities of flue gas desulfurization (FGD) gypsum. The program provides pivotal studies on leachability, groundwater transport, and mitigation of CCP constituent releases, as well as cost-effective and environmentally protective landfill/pond designs and closures. In addition, the program provides clear communications on the environmental risks associated with CCP management and a strong scientific voice on technical issues. Annual disposal costs for the industry are likely to increase significantly under the new EPA regulations; EPRI research indicates that hazardous waste regulation could increase disposal costs industrywide by $55 billion to $77 billion over a 20-year period.

EPRI research was instrumental in EPA’s finding of CCPs as nonhazardous in 1993 and again in 2000 under the Resource Conservation and Recovery Act (RCRA). When the Kingston dike failure in 2008 led EPA to reconsider national regulations for CCPs under RCRA, research in this program focused on technical issues and data gaps related to the regulatory drivers. Working closely with utility members, EPRI identified key technical issues with respect to costs, engineering, and environmental risk, and developed an extensive package of reports and information that was conveyed to EPA during the interagency review of the draft proposal and in comments on the rule proposed in June 2010.
Approach
This program builds on years of research evaluating environmental issues associated with CCP use and disposal. It shapes research to specific customer needs and to specific problems of greatest interest. The program coordinates research activities with those of other industry groups and federal and state research and regulatory agencies. This program delivers

- a robust CCP characterization database and environmental geochemistry assessments,
- health and ecological risk assessments associated with CCP disposal and use,
- guidelines and costs for the management and monitoring of disposal facilities,
- groundwater transport models and other assessment tools and data,
- remediation technologies specifically designed for CCP constituents, and
- data and tools to evaluate large-volume beneficial-use land applications.

Accomplishments
EPRI collaborates with governmental and nongovernmental organizations to communicate complex scientific data to regulatory agencies, policymakers, engineers, and the public on the environmental and engineering benefits of using CCPs. EPRI also works closely with EPA on research questions to provide technical support on regulatory matters affecting disposal, groundwater remediation, and large-volume land application uses. This work is closely coordinated with the CCP Use program in EPRI’s Generation Sector. Program accomplishments include

- preparation of detailed comments on technical issues raised by EPA in the 2010 CCR disposal proposal;
- analysis of the impact of potential alternative disposal regulations on power plant economics;
- technical evaluation of EPA-designated CCP damage cases;
- collection of a robust database on the leaching, volatilization, and potential risks from mercury in CCPs;
- laboratory and field data on CCP leaching and geochemistry;
- compilation and screening evaluation of groundwater remediation options for CCP constituents;
- preparation of comprehensive compilations of data on the occurrence, groundwater transport, treatment, and health effects of several key CCP constituents;
- upgrade of MANAGES data management software to include radionuclides;
- establishment of a nationwide network of sites to evaluate the use of FGD gypsum in agricultural applications; and
- assessment of risks associated with radionuclides in CCP solids and leachate.

Current Year Activities
Program research for 2012 will focus on compliance with new regulations, disposal site engineering and costs, evaluation and control of leaching from CCPs and products containing CCPs (for example, concrete), health and ecological risks associated with CCP management, CCP characterization using the new EPA leaching protocol, ash pond closure, and groundwater remediation. The program is responding to specific issues associated with the EPA proposed rule in 2011. The final CCP rule is expected in 2012. Research on ash ponds will be coordinated with that in the Effluent Guidelines and Water Quality Management program, which examines options for water treatment of ash pond discharges. Specific efforts will focus on

- research to assist in assessing and complying with the new federal regulations governing CCP disposal and use, including development of cost data;
- evaluation of health and ecological risks associated with trace constituents in CCP disposal and use settings;
- methods for fixating metals in ash;
- ash pond closure;
- evaluation of liners and caps for CCP disposal sites;
- ensuring the appropriate use of data from new leaching protocols being developed by EPA and others;
- continued development of groundwater quality signatures for assessing CCP impacts;
- completion of demonstrations of FGD gypsum use as an agricultural amendment;
- continued development of chemical profiles for additional key CCP constituents;
- development of data for assessing changes in CCP characteristics due to changing air emissions controls;
- development and/or evaluation of effective groundwater treatment and remediation methods for key constituents at coal piles and CCP disposal and use sites;
- determination of decision guidelines for the environmental acceptability of geotechnical uses of CCPs in structural fills, roadbase, and mine reclamation; and
- development of guidance regarding best practices for decommissioning of old power plants.

Estimated 2012 Program Funding
$1.2M

Program Manager
Kenneth Ladwig, 262-754-2744, keladwig@epri.com

Summary of Projects

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P49.001</td>
<td>Communications and Outreach</td>
<td>A variety of outreach and communication vehicles, including short articles, technical briefs, oral presentations, and workshops, will be used to convey research results from CCP research in a format that can be broadly disseminated to and understood by both technical practitioners and the general public.</td>
</tr>
<tr>
<td>P49.002</td>
<td>Groundwater and Environmental Risk Assessment</td>
<td>Research is focused on assessment and evaluation of groundwater effects and human health and ecological risks associated with the specific inorganic constituents that are commonly found at CCP management sites and other power plant facilities.</td>
</tr>
<tr>
<td>P49.003</td>
<td>Characterization of Coal Combustion Products</td>
<td>This research provides laboratory and field information on CCP characteristics and how CCPs behave in environmental settings.</td>
</tr>
<tr>
<td>P49.004</td>
<td>Management of Coal Combustion Products</td>
<td>This project uses a mix of laboratory information, field studies, and engineering evaluations to assess and develop environmentally sound and cost-effective CCP management practices.</td>
</tr>
<tr>
<td>P49.005</td>
<td>Groundwater Remediation and Site Restoration</td>
<td>This project provides information and technologies for groundwater remediation at CCP and coal pile sites and for restoration of former power plant properties.</td>
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P49.001 Communications and Outreach (069225)

Key Research Question
Research results are of value only if utility technical staff, regulators, and the public have ready access to them in a convenient form. Outreach efforts—user-focused briefing papers, conference presentations, websites, and personal visits—can provide a means of communicating key research findings to CCP managers and their regulators to help support economically sound and environmentally safe management practices.

Approach
Effective communication of EPRI research on CCP issues is essential if the results are to be considered and applied by the policymaking and regulatory communities. Communications activities under this program inform
decision making and support the development of scientifically sound environmental policy through effective dissemination of significant research results to EPRI members, policymakers, regulators, scientists, and the public at large. These results are communicated via

- succinct descriptions of key EPRI research findings and their implications on a timely basis;
- presentations, briefings, and testimony to key stakeholders;
- detailed summary papers on EPRI research and analysis on major issues; and
- critical reviews of external studies published in technical reports or technical papers.

Impact

EPRI's outreach efforts enable users to

- better communicate with government entities and the public,
- coordinate use of research with evolving regulations, and
- stay abreast with state-of-the-science technologies for disposal, use, environmental assessment, and remediation.

How to Apply Results

Environmental compliance and CCP management staff can use the technical briefs and short communications in meetings with community members, potential CCP users, and local regulatory authorities.

2012 Products

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<tr>
<td><strong>CCP Research Communications:</strong> A variety of outreach and communication vehicles, including short articles, technical briefs, oral presentations, and workshops, will be used to convey research results from CCP research in a format that can be broadly disseminated to and understood by both technical practitioners and the general public, focused on issues of most interest during the year.</td>
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<td>Technical Resource</td>
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Future Year Products

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<td>Technical Resource</td>
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<tr>
<td><strong>CCP Research Communications:</strong> A variety of outreach and communication vehicles, including short articles, technical briefs, oral presentations, and workshops, will be used to convey research results from CCP research in a format that can be broadly disseminated to and understood by both technical practitioners and the general public, focused on issues of most interest during the year.</td>
<td>12/31/14</td>
<td>Technical Resource</td>
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P49.002 Groundwater and Environmental Risk Assessment (058343)

Key Research Question

The need for environmental risk assessments at CCP disposal facilities and other power plant sites is expected to grow as monitoring requirements increase and EPA guidelines for new sites are enforced. Groundwater assessment costs alone can exceed $1 million per site, and potential health and ecologic effects from releases to surface water and air (dust) have not been fully characterized. Understanding potential risk is required to determine the need for further action and to select the optimum long-term plan for a site. Communication of the actual risk to the public and to regulators is critical to ensuring appropriate response actions.

In the past few years, releases of either ash or dissolved constituents from a handful of CCP management sites have significantly heightened public and regulatory interest in potential environmental risks associated with these facilities. The terms "toxic" or "hazardous" ash have recently become a standard part of the media and public lexicon. Scientific data, analysis tools, and objective evaluation are required to provide a fundamental basis for minimizing environmental impacts and for delineating real versus perceived risk at these sites.

Approach

Research is focused on the specific inorganic constituents that are commonly found at power plant facilities and are most likely to drive human health and ecologic risk. Chemical profiles are developed for key inorganic constituents of interest, providing comprehensive information on occurrence, geochemistry, attenuation, potential health effects, and remediation and treatment. The chemical profiles are supplemented by laboratory and field studies on chemical transport and potential exposure. This research also provides tools for assessing groundwater quality, and groundwater models for assessing and managing long-term risks associated with environmental releases.

Impact

This project provides power companies and other stakeholders with the information and tools to assess and communicate the risks and impacts associated with CCP management sites and other power plant facilities. The research results provide

- tools and data developed specifically for addressing groundwater issues unique to power plant facilities,
- risk assessment methodologies to facilitate assessment of potential liabilities and selection of cost-effective management strategies,
- cost savings realized with expedited groundwater investigations, and
- wide-ranging information from EPRI and literature sources on key constituents at CCP and coal pile sites.

How to Apply Results

The information and tools developed under this project will assist power companies in evaluating and communicating risk and compliance at CCP management sites and other power plant facilities. Compliance managers can use assessment techniques to identify and define issues and to evaluate the significance and long-term ramifications of impacts. Health and ecological assessment data provide a basis for communicating with the public on complex environmental issues. Summary compilations for specific constituents will provide companies with concise compendiums of information that will allow remediation and waste specialists to perform site-specific risk assessments and groundwater modeling, and to select appropriate response actions. Groundwater data assessment tools can be used to establish efficient compliance programs for collecting, managing, and analyzing the large volumes of data that will accompany increased monitoring and compliance requirements at disposal sites.
### 2012 Products

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<tr>
<td><strong>Chemical Profiles:</strong> Information for evaluating the transport and fate of key constituents at power plant sites is assembled into individual reports, or chemical profiles. These data include power plant source concentrations, other potential sources, geochemistry, attenuation coefficients, treatment/remediation technologies, and health and ecological effects. Chemicals are selected based on priority; currently, those of greatest interest are molybdenum, selenium, and chromium.</td>
<td>12/30/12</td>
<td>Technical Report</td>
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| **Health and Ecologic Risk:** Recent highly publicized CCP releases and heightened public concerns have highlighted the need for sound scientific information on human health and ecological risks posed by CCP management facilities. This research will develop information on documented risks as well as potential and modeled risks that participants can use to evaluate risks to groundwater, surface water, air, and soil for their facilities under various management and release scenarios. The primary focus is on human health risks, but ecologic risks will also be evaluated. A key component of the research is development of communication pieces to clearly convey relative risk information to the public. Focus topics include mercury, radionuclides, and trace metals such as arsenic, chromium, and selenium. | 12/30/12 | Technical Update |

### Future Year Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tr>
<td><strong>Chemical Profiles:</strong> Information for evaluating the transport and fate of key constituents at power plant sites is assembled into individual reports, or chemical profiles. These data include power plant source concentrations, other potential sources, geochemistry, attenuation coefficients, treatment/remediation technologies, and health and ecological effects. Chemicals are selected based on priority; currently, those of greatest interest are molybdenum, selenium, and chromium.</td>
<td>12/30/13</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>

| **Groundwater Quality Assessment:** Electric power companies are increasingly faced with monitoring multiple potential sources of groundwater contamination at power plant sites, including coal piles, ash ponds, ash landfills, and FGD management facilities. Distinguishing between on-site sources, as well as distinguishing on-site sources from potential off-site sources and background levels for compliance/remediation purposes, can be difficult. This research will develop data, methodologies, and tools for implementing groundwater quality monitoring and assessment programs, including use of groundwater quality signatures, stable isotopes, and groundwater models. | 12/31/13 | Technical Update |

| **Health and Ecologic Risk:** Recent highly publicized CCP releases and heightened public concerns have highlighted the need for sound scientific information on human health and ecological risk posed by CCP management facilities. This research will develop information on documented risks as well as potential and modeled risks that participants can use to evaluate risks to groundwater, surface water, air, and soil for their facilities under various management and release scenarios. The primary focus is on human health risks, but ecologic risks will also be evaluated. A key component of the research is development of communication pieces to clearly convey relative risk information to the public. Focus topics include mercury, radionuclides, and trace metals such as arsenic, chromium, and selenium. | 12/30/14 | Technical Report |
**Key Research Question**

Management options and environmental assessments for CCPs are driven largely by CCP physical and chemical characteristics. New and changing air emissions controls and advanced generation technologies substantively change the character of the by-products generated and their environmental behavior. Air emissions controls that impact CCPs from conventional coal-fired plants include nitrogen oxide reduction, mercury (Hg) control, and sulfur trioxide (SO₃) mitigation. Fuel blends include use of imported coals and increased use of biomass co-burning. Integrated gasification combined-cycle (IGCC) technology will generate a new class of by-products over the next decade. CCP radioactivity is under consideration again in light of technologically enhanced naturally occurring radioactive materials (TENORM) regulation.

Objectives of this research are to develop and assess characterization data that support appropriate regulatory decisions as well as selection of appropriate management alternatives and long-term risk evaluations. In particular, the new EPA Leaching Environmental Analysis Framework (LEAF) protocol will be applied, evaluated, and developed as it concerns CCPs. Data will be maintained in a readily accessible database. Complete characterization data and critical evaluation of those data are an ongoing need to support development of environmentally sound and cost-effective management strategies based on accurate characterization of potential environmental releases.

**Approach**

This research provides laboratory and field information on CCP characteristics and how CCPs behave in environmental settings. Data are maintained in the CP-Info database. The current focus is on application and assessment of the new LEAF leaching protocol, including field calibration/validation of the leaching results and development of methods for correctly interpreting the complex results of the protocol. In addition, work continues to clarify leaching geochemistry of trace elements and to develop geochemical models to describe the leaching phenomenon.

**Impact**

Research in this project provides core data touching all facets of CCP disposal and use. The information is used to provide technical underpinnings for regulation, management strategy, risk assessment, and remediation. The research results:

- allow power companies to evaluate the impacts of plant modifications, such as fuel changes, air emissions controls, and flue gas additives;
- inform the regulatory deliberations on management of CCPs under federal and state disposal regulations;
- support permitting, compliance, and groundwater assessment at CCP disposal sites;
- facilitate risk-based decision making considering the long-term behavior of CCPs in the environment; and
- support regulatory and public communications on environmental risks.

**How to Apply Results**

Engineers and scientists can use these data and tools to support a wide range of permitting and compliance activities at CCP management sites. A comprehensive database of CCP characteristics can be used as part of an overall risk-based management approach for CCPs. Reports on various air emissions control technologies and their impacts on CCPs can be used by CCP managers to make decisions on disposal and use alternatives. Summary brochures can be used to communicate those decisions to the public on sensitive issues.
2012 Products

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<tr>
<td><strong>Leaching Protocols:</strong> EPA recently released draft procedures for the LEAF leaching protocol that include four new procedures for which little data and no evaluation criteria exist. This project will evaluate the suitability of the LEAF method for CCP management applications, perform studies to calibrate/validate the method to field conditions, and develop methods for interpreting the data for risk-based management decisions.</td>
<td>12/30/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Environmental Testing of CCPs:</strong> Environmental testing of CCPs is required to determine management practices that control leaching and release of CCP constituents to an acceptable level. Testing needs are dictated by changes/differences in regulations, changes in CCPs due to new air emissions control technologies, changes in fuels and technologies (for example, biomass cofiring and IGCC), and changes in compliance limits. This project will focus on testing CCPs of all types to develop a robust database, including testing of other materials for comparison. Characterization data will be maintained in the CP-Info database. EPRI will explore the concept of developing a test network for ensuring development of high quality data using consistent methods.</td>
<td>12/30/12</td>
<td>Technical Resource</td>
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Future Year Products

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<tr>
<td><strong>Metals Leaching Geochemistry:</strong> Laboratory research on metals leaching geochemistry will focus on advanced leachate characterization protocols and on specialized testing to address specific release characteristics. Decision-support tools are being developed for using the laboratory results to evaluate long-term leaching characteristics. Leachate modeling will be used as input to a framework for assessing disposal and use options. Parts of this work are being coordinated with development of new EPA leaching protocols and interpretation and use of those data.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Environmental Testing of CCPs:</strong> Environmental testing of CCPs is required to determine management practices that control leaching and release of CCP constituents to an acceptable level. Testing needs are dictated by changes/differences in regulations, changes in CCPs due to new air emissions control technologies, changes in fuels and technologies (for example, biomass cofiring and IGCC), and changes in compliance limits. This project will focus on testing CCPs of all types to develop a robust database, including testing of other materials for comparison. Characterization data will be maintained in the CP-Info database. EPRI will explore the concept of developing a test network for ensuring development of high quality data using consistent methods.</td>
<td>12/30/14</td>
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P49.004 Management of Coal Combustion Products (058342)

**Key Research Question**

Disposal facilities are often subject to stringent design and management standards that do not recognize the unique characteristics and generally low toxicity of coal ash and flue gas desulfurization (FGD) products, along with the limited mobility of their chemical constituents in groundwater. Federal and state regulatory agencies are considering development of more-stringent requirements for all disposal facilities and large-volume land applications. These actions have the potential to significantly increase CCP disposal costs and decrease options for beneficial use, and they will certainly increase groundwater monitoring and compliance requirements at CCP management facilities.
The objective of this research is to assist companies in evaluating and selecting cost-effective management alternatives. The work will focus on compliance with new requirements under the Federal Resource Conservation and Recovery Act (RCRA), as well as states’ implementation of those rules. This work will include technology evaluations (for example, pond closure liners, caps, fixation) as well as cost assessment tools. In addition, the environmental implications of large-volume land applications will be evaluated.

**Approach**

This project uses a mix of laboratory information, field studies, and engineering and economic evaluations to assess and develop environmentally sound and cost-effective CCP management practices. The objective is to predict and control environmental impacts at CCP disposal and beneficial use facilities. The research explores options for fixation of trace metals in CCPs to reduce the potential for leaching and release, evaluates improvements and innovation in liners and caps, conducts research on the use of FGD gypsum in agriculture, and develops assessment tools for structural fill and roadbed applications. The information will be used to update the EPRI CCP disposal manuals for coal ash and FGD solids. Ash pond closure, monitoring, remediation, and redevelopment are of particular interest due to current regulatory options being considered under RCRA and the steam electric effluent limits guidelines, which could significantly limit or eliminate the use of wet management practices.

**Impact**

Disposal requirements for CCPs will almost certainly change over the next few years in response to recent events. Research under this project will provide technical information to inform the regulatory process, as well as to provide power companies with options for disposal and beneficial use that reduce long-term environmental liability in a cost-effective manner. The research results help to

- inform EPA rulemakings on management standards for CCP sites and mine placement,
- reduce CCP management costs,
- improve risk-based decision making associated with environmentally sound management practices,
- develop cost-effective closure and remediation of ash ponds, and
- establish guidelines for environmentally acceptable use of CCPs in large-volume land applications.

**How to Apply Results**

EPRI will use the broad information generated in this project to help inform rulemakings by the EPA and individual states on management of CCPs. Utility engineers and scientists can use the manuals and research results to ensure environmentally protective and cost-effective design and maintenance of disposal facilities using proven methods. Environmental data can be used by CCP managers to make risk-based decisions on the environmental suitability of land applications.

**2012 Products**

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<tr>
<td><strong>Metal Fixation in Ash:</strong> Leaching of trace constituents from CCPs often leads to more-stringent disposal requirements, based either on a state hierarchical scheme or federal risk assessment modeling. Such leaching can also prevent the use of CCPs in some geotechnical applications. This project will explore additives and management approaches to chemically or physically fixate trace constituents in fly ash, thereby reducing leachability and expanding flexibility with respect to management options.</td>
<td>12/30/12</td>
<td>Technical Report</td>
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Liners and Caps: Proposed federal regulations will require liners and caps for all CCP disposal sites. This research will evaluate liner and cap technologies suitable for CCP sites, perform tests on compatibility of clays and geosynthetic materials with CCP leachate, for bottom liners and explore alternative and innovative capping designs.

Reference Costs for CCP Disposal: Proposed CCP disposal regulations will substantially increase compliance costs. This research will develop costs for a variety of management options, including materials handling, disposal site design and operation, and wastewater/leachate treatment. The costs will be incorporated into spreadsheet-based software that can be used by power companies to evaluate the financial impacts of various management options.

Use of FGD Gypsum in Agriculture and Land Applications: FGD products will increase substantially in volume over the next ten years. Research will evaluate the environmental efficacy of using FGD gypsum and other FGD products for agricultural crops and related large-scale land applications, using a combination of laboratory tests and field plots in diverse geographic areas. Key environmental issues will be addressed, including the fate of mercury and other metals. This work is being closely coordinated with USDA and EPA. Deliverables will include site reports, risk assessments, and workshops.

Environmental Data for Geotechnical Applications: Structural fills and roadbase applications provide high-volume use opportunities for CCPs that do not meet specifications for use in products such as concrete and wallboard. These applications offer important alternatives to virgin materials in sustainable construction practices. Placement of CCPs in surface or underground mines offers several potential benefits, including highwall stabilization, land reclamation, subsidence control, and acid mine drainage mitigation. This research will develop risk-based approaches to evaluating the long-term risks and benefits, including life-cycle societal benefits, associated with these geotechnical applications.
The objective of this research is to evaluate the treatment and remediation options for inorganics commonly encountered at CCP sites and other power plant facilities. The universe of remediation options for inorganics is limited, and there has been little research on the specific mixtures of inorganic constituents commonly found at power plant CCP management facilities. The most commonly used methods are barriers (for example, slurry walls) and pump and treat. Passive in situ methods are largely undeveloped for CCP sites. Research is needed to provide data on the effectiveness and cost for a range of options, to tailor existing treatment and remediation methods to power plant sites, and to develop new technologies.

This project is related to the Site Closure, Redevelopment, and Green Remediation project (P50.004) in program 50; research in the two projects will be coordinated for maximum effectiveness. P50.004 deals with remediation and redevelopment of legacy sites, such as former manufactured gas plant (MGP) sites and other decommissioned power plant sites. The focus of P50.004 is on remediation of organic contaminants (such as polycyclic aromatic hydrocarbons from coal tars) and implementation of environmentally friendly technologies that minimize adverse overall environmental impact.

**Approach**

This project provides bench-scale treatability data specifically to address difficult-to-treat constituents such as boron, molybdenum, arsenic, chromium, and selenium. Field tests will be used in collaborative projects with power companies to refine the remediation technologies for chemical mixtures normally found at CCP and coal pile sites and to develop cost and engineering data. At retired power plant sites, a combination of soil and groundwater investigations, targeted remediation, and land use planning will be used to develop cost-effective site restoration strategies, in coordination with Program 50.

**Impact**

Soil and groundwater remediation are generally high-cost endeavors, and often the long-term outcome is uncertain. The research results from this project are designed to lower the costs and increase the effectiveness of targeted remediation and restoration at power plant sites.

- Remediation methods are evaluated and developed specifically to address the mix of constituents commonly found in soil and groundwater at power plant sites.
- Significant cost savings can be realized with prescreening of available technologies and targeted remediation.
- Site restoration research provides a database for closure and revitalization of retired properties.

**How to Apply Results**

The information and tools developed under this project will assist power companies in effectively addressing groundwater remediation and site restoration projects. Bench-scale laboratory data can be used by remediation teams to screen groundwater remediation technologies and select those most appropriate. Field demonstrations will provide remediation engineers with implementation data that will allow selection and design of appropriate remediation methods.

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<tr>
<td><strong>Groundwater Remediation Technologies</strong>: This research will track and evaluate innovative groundwater restoration technologies for inorganic chemicals, with emphasis on in situ methods such as reactive walls and geochemical barriers. Promising technologies will be further developed with field implementation under collaborative projects at CCP management sites and coal piles.</td>
<td>12/30/12</td>
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Future Year Products

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<tr>
<td><strong>Groundwater Treatability:</strong> This project provides bench-scale treatability data for the inorganic constituents found at CCP facilities and other power plant sites. These data provide the basis for pilot-scale or field-scale tests of emerging treatment methods. Focus is on removal of boron and oxyanions (arsenic, selenium, molybdenum, vanadium), with applicability in both above-ground and <em>in situ</em> applications.</td>
<td>12/30/14</td>
<td>Technical Update</td>
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Supplemental Projects

Pond Closure Research (072032)

Background, Objectives, and New Learnings

In June 2010, EPA proposed national regulations for disposal of coal combustion products (CCPs). One alternative included in the proposal was regulation as a special waste under Subtitle C (hazardous waste provisions) of the Resource Conservation and Recovery Act (RCRA). Regulation under Subtitle C would essentially result in complete conversion from wet handling of CCPs to dry handling and in closure of all active CCP ponds. A second alternative in the proposal was regulation as a solid waste under Subtitle D (nonhazardous waste) provisions in RCRA. While Subtitle D regulation would offer more opportunity to continue some wet handling practices, such as for bottom ash, it would still lead to a significant number of wet to dry conversions and closure of many CCP ponds. The EPA proposal includes an aggressive timeline for these closures, which will require special engineering practices in many instances. In addition, the rules may contain provisions for reclosing old ponds that do not meet the RCRA closure requirements.

An associated issue is the loss of wastewater treatment capacity when an active pond is closed. While replacement of wastewater treatment capacity is not a focus of this project, the costs and logistics should be considered in planning and implementing pond closures. This research will interface with ongoing EPRI work on wastewater treatment to ensure a continuum in research results that addresses the full picture.

Under any regulatory scenario, power plants will likely be closing a large number of ash and flue gas desulfurization (FGD) ponds over the next 10 years. The purpose of this project is to help power companies meet the challenges presented by the evolving regulations. These challenges include premature closures, accelerated closures, long-term stability, construction materials, monitoring strategies, and land use. By researching these issues, the public will benefit by gaining a better understanding of site conditions and any associated environmental risks.

Project Approach and Summary

The project will function as a source of information for pond closures and as a source to initiate research projects to investigate engineering and environmental aspects of pond closures. Web conferences will be held on an approximately quarterly basis to convene participants to exchange information, plan research, and deliver results. Additional meetings and site visits will be organized as appropriate. Specific research projects may include:

- monitoring of the potential for ash liquefaction prior to closure,
- accelerated dewatering methods,
- alternative covers,
- investigation of building over closed ponds,
- groundwater monitoring and environmental assessment,
- risk assessment for in-place closure,
- remediation for sites with groundwater impacts,
- alternatives for final land use, and
- leachate and wastewater treatment options (in coordination with the Effluent Guidelines and Water Quality Management program).

This project is designed by EPRI with advice from members and experts in environmental sciences and process engineering professions. The work will be complementary to, and not duplicative of, related research in the Coal Combustion Products - Environmental Issues research program. That research in 2011 will include projects on liners and caps, and preliminary work on building new landfills over old ash ponds. This supplemental project will build from that work and focus more on field instrumentation and data collection on a site-specific basis to evaluate conditions, document performance, and develop improved methods.
Benefits
The at-risk industry-wide costs of closing active ash ponds under Subtitle C are estimated to exceed $5 billion. Research associated with this project is aimed at assessing potentially escalated costs associated with a potential Subtitle C scenario which will potentially affect the public, private industry and the electric power industry alike. Additionally, this research will evaluate how the proposed Subtitle C rule may potentially affect the public and the power industry by increased land use requirements or additional disposal requirements. This figure does not include the extra engineering costs associated with an accelerated closure schedule or the stranded costs associated with early closure and lost capacity, and may significantly underestimate the cost of closing inactive ponds that do not meet RCRA standards. The benefits of this research are documentation and development of closure methods and monitoring practices that help ensure that closures are both cost-effective and environmentally protective.
Plant Decommissioning and Site Closure Interest Group (069779)

Background, Objectives, and New Learnings

The at-risk industry-wide costs of closing active ash ponds under Subtitle C are estimated to exceed $5 billion. Research associated with this project is aimed at assessing potentially escalated costs associated with a potential Subtitle C scenario which will potentially affect the public, private industry and the electric power industry alike. Additionally, this research will evaluate how the proposed Subtitle C rule may potentially affect the public and the power industry by increased land use requirements or additional disposal requirements. This figure does not include the extra engineering costs associated with an accelerated closure schedule or the stranded costs associated with early closure and lost capacity, and may significantly underestimate the cost of closing inactive ponds that do not meet RCRA standards. The benefits of this research are documentation and development of closure methods and monitoring practices that help ensure that closures are both cost-effective and environmentally protective.

Project Approach and Summary

This collaborative project will be conducted by EPRI staff, industry experts, and a consulting engineer. It will focus on the development of a comprehensive set of guidelines and checklists for planning and conducting a plant demolition project. Input from EPRI members and staff with experience in this area will be fully incorporated into all the guidelines. Any “lessons learned” during past projects will be included. In addition, to the extent that a full-scale plant decommissioning and closure project is implemented by an EPRI member during the course of this project, any insights gained from that project will be incorporated. This interest group complements other ongoing work at EPRI that is designed to help companies understand individual plant economics within the broader picture of the company’s strategic asset mix.

Benefits

As older power plants reach the end of their operational lives and sites are considered for repowering or other uses, systematic assessment and implementation of the removal of the plant equipment and infrastructure will be required. This project will provide participants and the public with knowledge on best practices for power plant decommissioning, closure, and demolition. The project can also offer opportunities to discuss additional options for site remediation, redevelopment, or repowering with emerging power generation technologies, such as biomass cofiring.
Manufactured Gas Plant Site Remediation - Program 50

Program Overview

Program Description

More than 1,500 former manufactured gas plant (MGP) sites in the United States require either investigation or remediation of contaminants, at estimated cleanup costs ranging in the tens of millions of dollars per site. Site managers need credible data and information on alternative investigation and remediation techniques, soil vapor intrusion (SVI), and air quality. Information on environmental and health risks from exposure to polycyclic aromatic hydrocarbons (PAHs), including naphthalene, requires evaluation to determine appropriate site-specific cleanup criteria.

The Electric Power Research Institute's (EPRI's) MGP site management research includes projects that assess site investigation methods and cost-effective alternatives for containment or remediation of contaminated soil, sediment, and groundwater. Program research informs regulatory deliberations and helps companies develop and implement cost-effective, environmentally protective management strategies for MGP sites. The program also addresses indoor air quality issues resulting from SVI into buildings situated near MGP sites.

Research Value

Using MGP site investigation and remediation research and development early in the process helps reduce cost, time, and uncertainty over the life of a remediation project. With development of an MGP site management strategy using a variety of program information and tools, research results project significant industrywide savings estimated at $37 million, with more than $2 million over the next 10 years targeting alternative background PAH cleanup levels. Use of improved methodologies for application of thermal desorption resulted in projected savings of $3.5 million at one site. In addition, a software tool demonstrating that natural attenuation was more cost-effective than active remediation saved one company an estimated $1 million per site.

Approach

The MGP site management program provides scientific data, methods, and tools for the efficient characterization, assessment, and remediation of former MGP sites. The program helps site owners improve control of emissions/odor issues, evaluates alternative methods for remediating and potentially redeveloping MGP sites, and monitors key health risk issues. This program delivers

- unique collaborative workshops and industrywide symposia;
- more than 20 years of EPRI and peer-reviewed publications and documentation, and a large network of experts;
- field studies assessing the viability of SVI investigation methods employing innovative techniques such as microbial genetic methods, forensic chemistry, moisture monitoring, and sorption sampling;
- modeling techniques such as the Remedial Assessment Options Model (ROAM), used to evaluate MGP site operations and maintenance costs, and the Model for the Assessment and Remediation of Sediments (MARS), used for assessing impacted sediment issues;
- methods for rapid screening of MGP sites, providing for more cost-effective and thorough site investigations; and
- evaluations of site remediation alternatives, including thermal treatment, in situ chemical oxidation, and coburning.
Accomplishments

This research advances the impacts of state-of-the-art investigation, assessment, and remediation of former MGP sites on soil, sediment, and groundwater. Modeling helps site managers evaluate cleanup alternatives, and the program responds quickly to emergent regulatory issues such as SVI and naphthalene risks. The program also assesses alternative site remediation measures, providing clear and issue-specific guidance to site managers on feasible options for specific site requirements. Program accomplishments include:

- Review of current vapor intrusion methods and implementation of a field-based research program;
- Analysis of indoor air results from vapor intrusion studies;
- Successful demonstration of rapid screening technologies;
- Identification of signature metabolites of monocyclic aromatic hydrocarbon (MAH) and PAH biodegradation in soil and sediments;
- Examination of PAH sources in urban background soils;
- Guidance on MGP-impacted sediment remediation, including monitored natural recovery and sediment capping; and
- Continuing evaluation of methods to assess the performance of MGP soils solidification and resources to determine the applicability, implementation, and assessment of soils solidification.

Current Year Activities

Program R&D for 2012 will focus on sediment characterization and investigation and evaluation of remediation technologies, including assessment of the applicability of "green" remediation. Specific efforts will include:

- Investigation of sediment characterization methods for assessing sources and weathering of PAHs;
- Evaluation of advanced chemical oxidation technologies for site remediation;
- Continued risk assessment evaluations of naphthalene and other relevant PAHs, including examination of EPA's Relative Potency Factor approach for determining the carcinogenicity of PAH mixtures, and EPA's Integrated Risk Assessment System (IRIS) reassessment of benzo(a)pyrene;
- Assessment and management of air emissions from remediation of MGP sites;
- Compilation of lessons learned from SVI investigations; and
- Assessment of MGP site closure and redevelopment and of applicability of green remediation technologies.

Estimated 2012 Program Funding

$.8M

Program Manager

Babu Nott, 650-855-7946, BNOTT@epri.com
### Summary of Projects

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<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P50.001</td>
<td>Sediment Remediation</td>
<td>This research project investigates MGP sediment sites with new methods to ensure effective and appropriate cleanups.</td>
</tr>
<tr>
<td>P50.002</td>
<td>Site Remediation Technologies</td>
<td>This research project provides information on the feasibility, effectiveness, regulatory acceptance, and costs associated with alternative MGP site remediation technologies.</td>
</tr>
<tr>
<td>P50.003</td>
<td>Risk Assessment Studies</td>
<td>This project evaluates research results and regulatory developments related to risk assessment of naphthalene, benzo(a)pyrene, and PAH mixtures.</td>
</tr>
<tr>
<td>P50.004</td>
<td>MGP Site Closure, Redevelopment, and Green Remediation</td>
<td>This project will identify and evaluate green remediation metrics and technologies that are appropriate for utility facilities.</td>
</tr>
<tr>
<td>P50.005</td>
<td>MGP Site Contaminant Characterization and Source Attribution</td>
<td>The research carried out in this project seeks to make site characterization and remedial assessments more effective and more acceptable to regulatory agencies.</td>
</tr>
<tr>
<td>P50.006</td>
<td>Air Monitoring and Soil Vapor Intrusion</td>
<td>Air monitoring and soil vapor intrusion studies will provide tools for utility managers to control potential hydrocarbon emissions from MGP sites during both remediation and subsequent use or development of the property.</td>
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#### P50.001 Sediment Remediation (Q55284)

**Key Research Question**

Remediation of coal tar-contaminated sediments remains an expensive and technically difficult problem for MGP site managers. There is a need to explore alternative remediation strategies such as monitored natural attenuation and recovery. Issues related to cleanup-level requirements remain tied to the toxicity of benthic and other aquatic organisms. It has been suggested by some agencies that point-source discharges may contribute to a watershed’s condition; therefore, background PAH or isotope studies may be needed. *In situ* technologies such as capping require further testing to be considered an alternative to dig-and-haul methods.

**Approach**

This project informs decision making by defining methods to delineate, evaluate, and remediate contaminated sediments. The work seeks to protect and restore aquatic environments. Millions of dollars of dredging costs may be avoided by using alternative means of capping or control. In 2012 and future years, research will consider background studies of PAHs in sediments; reviews of capping, monitored natural recovery, or other in-situ alternatives to dredging, including evaluation of biodegradation in capping systems; and documentation of field performance of a range of sediment remediation technologies. Included in this work will be support for the development of technical guidance by the Sediment Remediation Team of the Interstate Technology and Regulatory Council.

**Impact**

- Advanced assessment techniques, such as bioavailability testing, assist member companies with determining the location of “hot spots” in sediments.
- Acceptance of alternative, *in situ* remediation measures in lieu of dredging can potentially save hundreds of thousands of dollars in remediation costs.
- Forensic evaluations, such as isotope testing, can help to identify sources and background levels of contamination.
How to Apply Results

Members can use this information to more efficiently and effectively distinguish between sediment contamination from MGP sites and contamination from other sources. The results of this work will provide site managers with capping and containment alternatives. Field pilot tests will be strongly considered. Results will be delivered to members in technical and peer-reviewed reports. Briefings and presentations to regulatory agencies and the public will be available.

2012 Products

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<tr>
<td><strong>Background Studies of PAHs in Sediments:</strong></td>
<td>12/31/12</td>
<td>Technical Report</td>
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<tr>
<td>This technical report will be a review of case studies and methods used to successfully determine non-MGP related sources of contaminants.</td>
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<tr>
<td><strong>Sediment Bioavailability Database:</strong></td>
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<td>Technical Resource</td>
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<td>As sediment bioavailability projects are conducted, data from these projects will be gathered and results reviewed.</td>
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<td><strong>Biodegradation in Capping Systems:</strong></td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td>Recent projects indicate that contaminant biodegradation may be occurring within capping materials. The potential for this activity will be further assessed and methods will be developed that can be deployed in future projects to measure the occurrence of this phenomenon.</td>
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P50.002 Site Remediation Technologies (Q55810)

Key Research Question

Site managers are seeking remediation alternatives to dig-and-haul operations in places where there is limited ingress/egress or where buildings and roadways exist over a former MGP site. The use of in situ treatments such as chemical oxidation or solidification will be considered important technologies to investigate. Other in situ technologies, such as thermal treatment, containment wall, barrier, or aquifer modification technologies, may require further evaluation.

Approach

This work aims to reduce costs by providing information regarding performance data on remediation technologies. Research is aimed at saving companies millions of dollars where conventional dig-and-haul technologies cannot be applied. In 2012, the project will begin to pilot-test and evaluate in situ treatment technologies (such as S-ISCO, and chemical/biological methods using persulfate and peroxide), improve chemical delivery methods using vacuum or pulse wave technologies, and evaluate alternative product recovery methods.

Impact

- EPRI has already identified several reactive barrier additives that can cost-effectively remove MGP-related compounds from groundwater, thus reducing long-term operation and management costs.
- Selecting the appropriate in situ chemical oxidant and its delivery method can save hundreds of thousands of dollars per site with correct application.
- EPRI has documented that one innovative application of a thermal desorption process for treatment of heavily impacted MGP soils may save more than $3 million for one utility.
How to Apply Results

The results of this work may be applied by site managers who want to determine whether an in situ technology can be used as an alternative remediation strategy. Briefings will be made to federal and state regulatory agencies as appropriate or needed. Development of technologies for remediating MGP wastes may take several years from bench-scale to field-scale pilot tests.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Proof of Concept Studies of Advanced Remediation Technologies:</strong> Studies will be conducted</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>to evaluate claims made for new remediation technologies. These technologies may include</td>
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<td>soil smoldering, large-diameter steam augers, advanced chemical oxidation using permanganate/</td>
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<td>persulfate, S-ISCO, or biologically assisted remediation.</td>
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Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td><strong>Develop Website with Information on MGP Remediation Projects:</strong> This research will</td>
<td>12/31/13</td>
<td>Technical Resource</td>
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<tr>
<td>provide case histories of MGP remediation projects in the United States and internationally.</td>
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<td>Case histories could include completed as well as ongoing projects. Using a web-based</td>
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<td>database would facilitate updating of the case histories.</td>
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<tr>
<td><strong>Tracking Advances in Remediation Technologies at MGP Sites:</strong> This work will monitor and</td>
<td>12/31/14</td>
<td>Technical Resource</td>
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<tr>
<td>report on uses of advanced technologies for investigation and remediation of MGP sites.</td>
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P50.003 Risk Assessment Studies (058346)

Key Research Question

Coal tar contains a number of polycyclic aromatic hydrocarbons (PAHs), exposure to which can be associated with increased probability of cancer incidence. Remediation endpoints for sites contaminated with coal tar are driven by the carcinogenicity of these compounds, which include benzo(a)pyrene and naphthalene. Conflicting data on the human carcinogenicity of some of these compounds have led to the development of conservative cleanup criteria. Cleanup levels that are risk-based and that remain protective of human health may result in a significant reduction in remediation costs.

Approach

This project tracks recent developments in the scientific literature and assesses the data to establish scientifically sound risk-based cleanup levels. This research will inform the regulatory process by delivering accurate and credible scientific information regarding the environmental and health risks from MGP site contaminants. It will focus on naphthalene research to evaluate evidence that naphthalene is a possible human carcinogen and will evaluate EPA’s IRIS program results. The research will also examine developments regarding EPA’s Relative Potency Factor approach for determining the carcinogenicity of PAH mixtures, as well as the IRIS reassessment of benzo(a)pyrene.
Impact

- Improves understanding of health risks associated with contaminants at MGP sites, leading to a more informed regulatory process for EPA and others that set standards and cleanup-level requirements
- Improves risk-based decision making and reduces long-term costs
- Supports public interest research

How to Apply Results

MGP site owners and managers will gain value from this research through an improved understanding of how to evaluate and manage the risks of certain PAH compounds. Site managers will gain value from this work by considering how the impact of certain compounds such as naphthalene will play a role in determining specific risk-based cleanup criteria in soil and groundwater. Members should ensure that findings from the project are communicated widely, sending results to key stakeholders, making sure that stakeholders understand the findings, and suggesting that the findings be considered in the development of environmental policy. Members should also use this information to communicate with various public groups as necessary. In addition, EPRI staff will hold periodic briefings for members and key stakeholders, including regulatory and other government agencies, as appropriate.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Risk Assessment Communication and Support:</strong> This deliverable consists of communication to members on relevant issues, tracking of regulatory developments, and preparation of comments as appropriate.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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Future Year Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Risk Assessment Communication and Support:</strong> This deliverable consists of communication to members on relevant issues, tracking of regulatory developments, and preparation of comments as appropriate.</td>
<td>12/31/13</td>
<td>Technical Resource</td>
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P50.004 MGP Site Closure, Redevelopment, and Green Remediation (067511)

Key Research Question

New "green" remediation paradigms are being developed and implemented by state and federal agencies. Green remediation evaluations may be required at utility legacy sites such as former MGP sites. While many existing technologies may meet green remediation criteria, additional research is needed to identify green remediation technologies, to evaluate green remediation standards and criteria being developed by standards organizations and others, and to develop and evaluate new metrics for determining the environmental footprints of remediation projects.

This project is related to the Groundwater Remediation and Site Restoration project (P49.005) in program 49; research in the two projects will be coordinated for maximum effectiveness. P49.005 deals with groundwater remediation at coal combustion product (CCP) facilities and the redevelopment of such sites after their useful life. The focus of P49.005 is on remediation of groundwater contaminated with inorganic contaminants (such as boron, sulfate, arsenic, selenium, and chromium). Project P50.004 is focused on organic constituents.
Approach
In 2012, this project will begin evaluation of case studies for determination of the impacts of nonaqueous phase liquids (NAPL) on groundwater. This work will also develop methods and approaches for addressing increased interest in green remediation, including possible development of models of carbon emissions from various remediation alternatives, alternative construction approaches, and green remediation technologies.

Impact
- Evaluates the cost of remediation on a site-specific basis, providing managers with dollars-per-ton or dollars-per-acre removal estimates, which can be used for better forecasting
- Provides best-practices examples using management oversight review
- Provides site managers with alternative use assessments through case studies of completed projects requiring no further action
- Enables end-use evaluations using varying end-use visions

How to Apply Results
Workshops will provide technology transfer to inform members of current thinking on green remediation principles and projects. Reports will be prepared on methods and procedures for evaluating green remediation technologies and their environmental footprints.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Green Remediation Model at MGP Sites:</strong> Standards are being developed by regulators and nongovernmental organizations for implementing green practices at remediation sites. These green standards are being developed to apply to all phases of a remediation project, including site investigation, remedy selection, construction, and long term operation and management. The purpose of this project would be to provide examples of how these standards might be applied at MGP sites and to identify what green methods are available that might be relevant at MGP sites.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>NAPL in Groundwater Case Studies:</strong> This research will identify and review case studies where NAPL impacts to groundwater have occurred at MGP sites. Investigation methods and results will be identified along with measures taken to address these impacts.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<tr>
<td><strong>Development of Technical Protocol for RI/FS Studies at MGP Sites:</strong> Complex MGP sites require remedial investigations and feasibility study work plans that are more advanced than those required for many other contaminated sites. This project would develop a more focused approach specifically applicable for MGP sites and might include standard assumptions as well as sustainability options for all aspects of these projects.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Standard Practices for Utility Workers at MGP Sites:</strong> Water and sewer utility workers are often called upon to perform subsurface work at MGP sites. This project would seek to develop a training manual that could be provided to these workers that would identify work practices to be followed to protect worker safety and health.</td>
<td>12/31/13</td>
<td>Technical Resource</td>
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</table>
Generic Site Management Plans: Many remediated MGP sites must develop plans for postremediation work at the site. Such work must ensure that engineering and institutional controls are maintained during site operations and management activities. This project would seek to develop a generic plan that could be applied for most MGP sites.

12/31/14 Technical Update

P50.005 MGP Site Contaminant Characterization and Source Attribution (Q55325)

Key Research Question
Gaining regulatory acceptance of some rapid-characterization screening techniques to determine the physical and chemical extent of coal tar in soils still remains a challenge for site managers. More data are needed from some rapid-characterization techniques to prove that they are acceptably rigorous in meeting regulators’ requirements. The assessment of the effectiveness of the in situ stabilization (ISS) process for containment of PAHs from treated MGP soils also poses significant challenges to site managers. There is a need to develop and demonstrate an alternative assessment methodology for ISS materials containing PAHs. In addition, characterization of soils in difficult-to-access locations, such as under buildings, remains problematic.

Approach
This project will deliver new and improved methods for rapidly characterizing and delineating coal tar in soil. It will evaluate steady-state conditions and study mobility of coal tar as well as evaluate rapid-characterization techniques for delineating the presence of coal tar in the subsurface, including dense NAPL (DNAPL) in bedrock. Work will include research on techniques for characterization of contamination in difficult-to-access structures and areas.

Impact
- This work improves risk management and decision making by delivering more cost-effective methods for delineating the extent of contaminated soils.
- Treating contaminated soils from MGP sites treated with cementitious binders and disposing of them in situ prior to capping and rehabilitation of a site can provide an cost-effective alternative solution to remediation.
- An EPRI background-PAH project gained regulatory acceptance in Illinois and is predicted to save millions of dollars over the next decade.

How to Apply Results
Members participating in this work will be able to use the results to better evaluate and delineate contaminant source areas, saving companies money on excavation costs. Results will help site managers provide preremedial design alternatives. Results also may be used by site managers to apply more-appropriate cleanup strategies based on background data. Results will be delivered primarily through publications and peer-reviewed literature. Participants in this work are encouraged to distribute results widely to regulators as warranted.

2012 Products

Closing Data Gaps: This work will convene a workshop to explore methods for closing data gaps at MGP sites, particularly as they might apply in inaccessible areas and bedrock.

12/31/12 Technical Resource
Future Year Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Use of Tracers for MGP Site Assessments:</strong> This project would review the state of the science for the use of tracers to determine groundwater and subsurface impacts associated with contaminants at MGP sites.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Update Remedial Options Assessment Model (ROAM):</strong> ROAM has been used to evaluate remedial alternatives at a number of MGP sites since it was released in 2004. However, it needs to be updated for use with current computer operating systems as well as to improve on the groundwater flow algorithms contained in the model.</td>
<td>12/31/14</td>
<td>Software</td>
</tr>
<tr>
<td><strong>High Temperature Field Probe with 3-D Visualization:</strong> Previous EPRI research identified the potential application of a heated transfer line-membrane interface probe for use in MGP site characterization. The utility of this equipment would be enhanced by coupling it with 3-D visualization capabilities to allow for rapid assessment, in the field, of MGP contaminant distributions.</td>
<td>12/31/15</td>
<td>Hardware</td>
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**P50.006 Air Monitoring and Soil Vapor Intrusion (Q55813)**

**Key Research Question**

Release of volatile organic compounds (VOCs) from soils or groundwater at MGP sites can cause soil vapor intrusion (SVI) into buildings or can cause odor or VOC emissions during excavation of contaminated soils. These issues are receiving increased regulatory attention through guidance documents or permit requirements from regulatory and health agencies. Costly SVI investigations are being required on or near MGP sites, and mitigation is sometimes required. Perimeter air monitoring during remediation is also usually required, but uncertainty still exists on how to interpret the data obtained.

**Approach**

This project improves decision making and risk management by providing state-of-the-art science and technology information on ambient and indoor air quality. The project characterizes air emissions and odors during site excavation and investigates subsurface vapor intrusion to indoor air and mitigation system performance.

**Impact**

- Improved methods for assessing SVI at MGP sites will help utility managers reduce costs and uncertainty in complying with regulatory or third-party requirements.
- Investigations into low-cost/low-technology SVI mitigation measures may reduce long-term costs and liability.
- Improved tools to predict, measure, and control odor and VOC emissions during MGP site remediation will reduce complaints and work delays and will provide important documentation to reduce postcleanup litigation.
- Improved air monitoring methods will provide more-complete, more-timely analytical data to evaluate potential off-site emissions.

**How to Apply Results**

MGP site owners and managers can use the results to make better evaluations of how odor is quantified and managed during remedial actions. MGP site managers can use the results of SVI data to evaluate risks so that remedial action plans are more thoroughly managed with respect to exposure issues.
## 2012 Products

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<th>Product Title &amp; Description</th>
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<tr>
<td>Monitor Developments in SVI Guidance and Air Monitoring: This research will monitor changes</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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<tr>
<td>in federal soil vapor intrusion guidance and issue development within the SVI technical</td>
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<td>advisory community. It will provide opportunities to assist members with air monitoring</td>
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<td>or odor control during site remediation.</td>
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## Future Year Products

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<td>or odor control during site remediation.</td>
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Program Overview

Program Description

Current and future air toxics emission, water discharge, and solid waste disposal regulations will result in increasingly stringent limits and increased compliance costs for power companies and other industrial emissions sources. On May 3, 2011, the U.S. Environmental Protection Agency (EPA) published a proposed Maximum Achievable Control Technology (MACT) rule that would regulate mercury and other hazardous air pollutant (HAP) emissions from coal- and oil-fired power plants. EPA relied on the data collected during the HAPs 2010 Information Collection Request (ICR) for the MACT rulemaking. Poor data quality can result in unrealistically low emission limits; control technologies for achieving such low limits can be extremely expensive, if not impossible, to implement.

There is a critical need to address environmental releases in a holistic, multimedia (air, land, water) manner so that a pollutant removed by a control technology from one medium (such as air) does not adversely affect the regulatory situation in other media (such as water or solid waste). There also will be an increasing need to minimize the environmental footprint of power plants, achieved through further optimization of existing power plant operations and design of new plants. The multimedia research in this program is focused on understanding the chemistry and partitioning of pollutants in the process streams of power plants. The research will be coordinated with related work in EPRI's Technology Innovations Program on emissions from emerging fossil generation technologies.

The Electric Power Research Institute's (EPRI's) Power Plant Multimedia Toxics Characterization program provides methods and tools for measuring and managing potentially toxic emissions and discharges from power plants, and prepares power companies to meet evolving regulations. The program helps industry, the scientific community, and the public evaluate discrete multimedia environmental impacts as well as the interplay between these receiving media that might result from changes in fuel composition or fuel blend, implementation of new or enhanced control technologies, or changes in plant operating practices. Information generated from this program will become more critical in view of EPA’s recently proposed rules for all HAPs, including mercury, other trace metals such as arsenic, acid gases including hydrochloric acid, and organics including dioxins/furans. Further, new environmental controls may impact discharges to the various media. Early data may be important in system design and in identification of potential issues.

Research Value

EPRI began its power plant toxics characterization research well before the 1990 Clean Air Act Amendments that established the HAPs program. This longevity positions the program as a visionary effort that anticipates issues, helps inform evolving regulations, and develops practical solutions. Characterization of power plant emissions and discharges requires accurate and sensitive analytical methods; where these do not exist, this program supports method development studies. The program addresses environmental impacts from advanced generation technologies such as integrated gasification combined-cycle (IGCC), as well as from alternative fuels such as biomass. The program continues to enhance understanding of the chemistry of pollutants in power plant streams and to provide methods and tools to accurately characterize the chemicals; this work facilitates development of more-effective control strategies for their management. The program also assists generators with permitting and reporting processes by providing credible emissions data. This research helps power companies

- monitor and, if necessary, control important HAPs;
- meet potential regulatory requirements at least cost; and
- design and operate plants that minimize overall chemical releases to all media.
**Approach**

The Power Plant Integrated Systems Chemical Emissions Studies (PISCES) Database is the most comprehensive data set available on HAPs emissions. It is a multimedia database containing primary information on the concentration and fate of substances in power plant process and discharge streams. The program also assists with Toxics Release Inventory (TRI) reporting and record-keeping requirements. This approach helps minimize the cost of overall environmental compliance and management. This program delivers

- accurate multimedia characterization of chemical substances from fossil fuel power plants (EPRI is providing a review and synthesis of the available ICR data, which will be critical in informing the HAPs MACT rulemaking);
- sampling and analytical methods that can reduce the risk of permit violations;
- significant cost savings from use of the PISCES Database and TRI reporting software (Toxics Release Inventory for Power Plants); and
- early warning of emerging issues, warning that can inform the development of technology and address potential environmental and public perception issues.

**Accomplishments**

Program research from this program has credibility with regulators as a source of objective and critical, scientific information. Data generated from this program is valuable to power companies in improved plant operation and cost-effective environmental compliance. Program accomplishments include

- PISCES power plant mercury characterization data provided critical information to industry and regulators during the development of the Clean Air Mercury Rule and played a key role informing the debate.
- A recent PISCES Database update should help power companies respond to the ongoing HAPs MACT rulemaking.
- EPA approved QuickSEM as a mercury emissions reference method (EPA Method 30B), a cost-effective sorbent-tube continuous mercury emissions monitoring system jointly developed and tested with EPRI's Generation Sector.
- An assessment of the multimedia fate of mercury in power plants with selective catalytic reduction and wet flue gas desulfurization systems.
- The program provided updated tools for environmental compliance and improved plant operation (PISCES Database and TRI software).

**Current Year Activities**

Program R&D for 2012 will continue to focus on toxics characterization data collection, as well as on synthesis of the 2010 HAPs ICR data, PISCES database population, multimedia characterization methods, and multimedia environmental impact evaluations of biomass- and coal-based generation technologies. The program will

- synthesize all of the 2010 HAPs ICR data, as well as related EPRI and U.S. Department of Energy (DOE) data, and, based on that synthesis, provide technical guidance to member companies in their plans to comply with the final MACT rule;
- fill data gaps in power plant emissions estimates for trace metals, including arsenic and selenium; acid gases such as hydrochloric acid and hydrofluoric acid; mercury; and other HAPs, including organic compounds;
- continue populating the PISCES database with power plant waste stream characterization data to document sampling and analytical methods used to meet TRI needs;
- evaluate, develop, and validate sampling and analytical methods for multimedia (gas, liquid, and solid streams) characterization, using PISCES as the clearinghouse for media-specific sampling and analytical methods; and
- evaluate multimedia environmental impacts of fuel changes, including renewable sources (for example, biomass) and control technologies on conventional generation plants, and IGCC systems.
Estimated 2012 Program Funding

$1.4M

Program Manager
Babu Nott, 650-855-7946, BNOTT@epri.com

Summary of Projects

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P59.001</td>
<td>Flue Gas Toxics Characterization</td>
<td>Power plant flue gas measurement data from many field studies will be synthesized and limited field testing will be conducted as necessary to address data gaps. The data will be evaluated to provide tools for estimating mercury and HAPs emission estimates and for complying with the final MACT rule.</td>
</tr>
<tr>
<td>P59.002</td>
<td>Sampling and Analytical Methods</td>
<td>This research provides an information resource to aid in selecting sampling and analytical methods for chemicals in power plant waste streams, and develops and validates new or improved methods where necessary.</td>
</tr>
<tr>
<td>P59.003</td>
<td>Multimedia Environmental Impacts - Conventional and IGCC</td>
<td>Power plant measurements are being conducted and the results evaluated to develop the database and tools to assist power plant personnel in understanding and managing their multimedia discharges with coal switching and new control technologies.</td>
</tr>
<tr>
<td>P59.004</td>
<td>TRI Technical Needs</td>
<td>TRIPP is a software program used to estimate releases of chemical substances to air, water, and land from coal-, oil-, and gas-fired power plants for purposes of TRI reporting.</td>
</tr>
<tr>
<td>P59.005</td>
<td>PISCES Database</td>
<td>The PISCES Database is a comprehensive, online database containing information on the concentration and fate of chemical substances in power plant process and discharge streams. It will be maintained and upgraded to maintain and increase its capability as the premier repository of EPRI power plant toxics characterization data. New data will be added to increase its usefulness.</td>
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P59.001 Flue Gas Toxics Characterization (101138)

Key Research Question

In May 2011, EPA issued a proposed rule that would regulate HAPs emissions from coal- and oil-fired power plants. A final rule is expected by November 2011. The proposed rule was based on the top-performing units for control of selected HAPs, specifically total particulate matter (which includes filterable particulate and condensables) as a surrogate for the nonmercury trace metals, hydrochloric acid as a surrogate for acid gases, and mercury. Alternative standards were also proposed for all of the individual trace metals as well as total metals (the sum of the various metals). As stakeholders provide comments and respond to the proposed rule, it is critical that EPA and all stakeholders have the best data available.

Power plants are now evaluating compliance approaches for meeting all the proposed HAP standards. Power plant owners/operators need to understand the impacts of coal choice and of power plant design and operation on the removal of all HAPs. Additional measurement data may be required to support sound compliance management. Power plants will need continuous monitors as well as approaches to conducting QA/QC tests (for example, relative accuracy test audits).
**Approach**

This project will provide the best information available to assist all stakeholders as the regulations are finalized and implemented. The project has provided guidance to utilities for accurate collection of HAPs emissions data, including trace metals, acid gases, and organics, as part of EPA's ICR for data from coal- and oil-fired power plants. EPRI has conducted a comprehensive review and synthesis of the ICR data, and is incorporating the variability of HAPs emissions measurements in MACT standard setting.

The U.S. power industry needs to understand the impacts of coal choice and of power plant design and operation on expected HAPs removals. In 2012, this project will

- continue to review and synthesize available emissions data, including the 2010 ICR data, and to update industry estimates of HAPs emissions from coal- and oil-fired power plants;
- support development of cost-effective emission control strategies for nonmercury HAPs; and
- refine existing correlations to predict trace metal HAPs (such as mercury, arsenic, and hydrochloric acid) emissions and removal based on coal type and control technology.

**Impact**

- Provides accurate and reliable data to support power plants in developing sound and cost-effective HAPs compliance strategies for mercury, total particulate matter, hydrochloric acid, and individual trace metals
- Provides predictive correlations for mercury and other HAPs for all key coal types and control technology configurations

**How to Apply Results**

Project findings and deliverables will be used by power company staff in environmental affairs/controls to assist power plants in developing management options for mercury and other HAPs. The results will assist engineering staff (design and operations) in developing and implementing effective management options for controlling HAPs emissions from power generation facilities. EPRI staff will also communicate the results to key stakeholders such as regulatory agencies, environmental policymakers, and the public.

**2012 Products**

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<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Summary: HAPs Emissions from Power Plants:</strong> This report will include review of all the ICR and previous EPRI, DOE, and host utility data for the key HAPs, including total particulate matter, mercury, hydrochloric acid, and various trace metals, for various coal/control configurations that are in the final HAPs rule.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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**Future Year Products**

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<tr>
<td><strong>HAPs Emissions from Power Plants:</strong> Depending on the exact details of the MACT final rule, technical analysis and data synthesis will continue to address data gaps; results of the analyses will be included in the technical update.</td>
<td>06/30/13</td>
<td>Technical Update</td>
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</table>
P59.002 Sampling and Analytical Methods (065616)

Key Research Question

Accurate characterization of potentially toxic chemicals in fuels, reagents, intermediate streams, air emissions, liquid and solid waste streams, and other discharges is essential for developing effective strategies for multimedia management of these chemicals. Some existing sampling and analytical methods do not have the required sensitivity or specificity to meet increasingly stringent regulatory needs. Better methods, and validation of existing methods, are needed to support compliance monitoring. The research conducted in this project will be targeted toward the most pressing needs of the industry, as determined by changes in regulations or fossil-fueled power plant technology. Methods that are likely to require improvement or validation include metals in flue gas desulfurization (FGD) wastewaters and stack gases, and fine particulates (PM$_{2.5}$) in flue gas from wet FGD systems. The drivers for this research are regulatory programs that require new pollution control technologies and impose increasingly strict limits on emissions to air, land, and water. For example, plants that install FGD systems will divert some metals from stack gas to wastewater. Power plants facing lower surface water discharge limits for these metals may not be able to measure them accurately with existing analytical methods. Techniques to avoid contaminating the samples will become increasingly important.

Approach

This project will continue work on sampling and analytical methods, and will deliver timely information and guidance to aid power plant staff in selecting and implementing appropriate sampling and analytical methods. The project will also support development and testing of new or improved methods where needed. Work on this project will be coordinated with work in other EPRI programs, as appropriate (for example, work on analytical methods for metals in FGD waters will be coordinated with work in Program 56, Effluent Guidelines and Water Quality Management).

Impact

Availability of suitable sampling and analytical methods is critical for accurate characterization of power plant streams. This work will enable development of effective strategies for management of these chemicals, and will assist power plant staff to

- minimize or eliminate potential violations of permit limits due to sampling or analytical inaccuracy,
- select appropriate methods for particular study objectives,
- inform regulators and other stakeholders of the quality and representativeness of monitoring data, and
- make good decisions in purchasing or contracting analytical laboratory equipment and services.

How to Apply Results

Project findings and deliverables will be employed by personnel in chemistry labs and environmental affairs/compliance departments of power companies to help them apply the most suitable sampling and analytical methods to meet regulatory and other needs. These personnel can also use the information to negotiate reasonable permits and to respond to EPA and state agencies in developing sound environmental regulations. Members should share the results with key stakeholders, ensure that stakeholders understand those results, and suggest that results be considered in the development of permit limits and environmental policies. The results will also assist engineering staff (design and plant operations) to accurately measure the concentrations of chemicals of concern and to help develop and implement effective management options for controlling release of toxic substances from generating facilities.
### 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Analytical Methods for Metals in Plant Wastewaters</strong>: This project will complete work initiated in 2011 to develop guidance for laboratories for best practices for analyzing complex power plant wastewaters such as FGD effluent. The research will develop procedures for analyzing selected trace metals using inductively coupled plasma mass spectrometry (ICP-MS) equipped with collision reaction cell modifications. Results will be described in the technical update.</td>
<td>09/30/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Analytical Methods Index</strong>: The Analytical Methods Index, a resource for identifying chemical analysis methods for trace substances in power plant stack gas, wastewater, fuel, and combustion products, will be maintained and improved by adding new content as needed.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Evaluation and Improvement of Particulate Test Methods</strong>: Compliance with more-stringent limits on particulate emissions will require more-accurate and precise methods for measuring PM emissions. This project will target improvement of current methods and development of better methods for measuring condensable particulates and PM2.5. Research results will be included in the technical update.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

### Future Year Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td><strong>Analytical Methods for Metals in Stack Gas</strong>: Although the use of unmodified ICP-MS for power plant wastewaters is known to lead to overestimation of concentrations of some metals (such as arsenic and selenium) due to polyatomic interferences, no study has yet looked at the same issue in samples collected for stack gas metals analysis using EPA Method 29. This project will evaluate the accuracy of common analytical techniques for stack gas metals analysis; results will be included in the technical update.</td>
<td>03/31/13</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

### P59.003 Multimedia Environmental Impacts - Conventional and IGCC (063346)

#### Key Research Question
As a trace element (for example, mercury or selenium) is removed from one medium (such as air), this pollutant is transferred to other media (water, solids, or both). Understanding multimedia fate is critical for sound environmental management as well as for responses to state and local regulatory drivers. The recently proposed HAPs MACT rule incorporates total particulate matter (which includes condensables) to address selenium. Renewable energy portfolio requirements in many states are leading to new interest in alternative fuel sources (such as biomass and biofuels) as well as in distributed generation. The potential for multimedia environmental issues associated with use of these energy sources must be fully understood.

#### Approach
This project will improve understanding of the fate of chemicals in power plant systems, leading to cost-effective management in both central station and distributed generation facilities.

- The research will continue to assess the multimedia fate of selenium and other trace elements in power plant streams.
In 2012, for conventional plants, the project will begin characterization of changes to air, water, and land releases from fuel changes (for example, low- to high-sulfur coal as well as alternative fuels such as biomass or biofuels) and new control technologies (for example, activated carbon).

For IGCC plants, the project will characterize waste streams and evaluate impacts.

Impact

- Assists power plant environmental engineers and compliance staff in evaluating the impact of changing fuels and controls on the fate of toxic chemicals in power plants
- Assists power plants in managing multimedia impacts and responding to state and local issues

How to Apply Results

Project findings and deliverables will be employed by personnel in environmental affairs/compliance departments of power companies in responding to EPA and state agencies in developing sound environmental regulations and permits. Members should share the results with stakeholders, ensure that stakeholders understand those results, and suggest that results be considered as environmental policies are developed. The results will also assist engineering staff (design and operations) in developing and implementing effective management options for controlling toxics emissions from power generation facilities. EPRI staff will also communicate the results to key stakeholders such as regulatory agencies, environmental policymakers, and the public.

2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td>Update: Multimedia Fate of Selenium in Power Plants</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

P59.004 TRI Technical Needs (100809)

Key Research Question

Power plant owners must report emissions of specific compounds to state and federal regulators. This process can be very labor intensive, as environmental department staff must spend many hours in compiling, analyzing, and reporting the required data. It is also necessary to maintain records of regulatory reporting and to defend assumptions made in estimating emissions if questions are raised by regulators.

Approach

This project, which is a continuing effort, develops emission factors for power generation facilities. The products assist companies in responding to EPA’s Toxics Release Inventory (TRI) reporting requirements, applying for permitting of new and existing facilities, and conducting “what-if” analyses to assist in planning new pollution controls and fuel changes. The project provides technical approaches, software, emission factors, and data evaluation to reduce reporting costs and improve release estimates. EPRI’s Toxics Release Inventory for Power Plants (TRIPP) software helps users estimate chemical substance releases to air, water, and land. It is updated regularly to reflect changes in EPA’s TRI program and changes to power generation and pollutant control technologies.

Impact

- Provides rigorous and credible estimation techniques and emission factors
- Reduces costs for preparing TRI reports and other emissions reports (one member estimated annual savings of $500,000 from the use of EPRI’s TRIPP software versus manual methods of preparing TRI reports)
- Standardizes the industry approach to emissions estimation, thus improving acceptability to regulators
- Allows "what-if" analyses to evaluate impacts of fuel changes or new pollution control equipment

**How to Apply Results**

The TRIIP software for TRI reporting can be implemented by environmental department staff or plant engineers on a Windows-based workstation. Data from plant operations (such as coal burned and hours of operation) are entered into the software. The resulting estimates are uploaded directly into EPA’s web-based Toxics Release Inventory—Made Easy (TRI-ME Web) reporting software, avoiding the need for manual data entry. Training and support are provided as part of the project to help staff learn and use the program. Emissions estimation models for sulfuric acid and ammonia will be provided as part of the TRIIP program and documentation.

**2012 Products**

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td>TRI for Power Plants: TRIIP software will be updated to reflect changes in EPA’s TRI program and improvements recommended by software users.</td>
<td>09/30/12</td>
<td>Software</td>
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</table>

**Future Year Products**

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td>TRI for Power Plants:</td>
<td>09/30/13</td>
<td>Software</td>
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</table>

**P59.005 PISCES Database (100807)**

**Key Research Question**

Companies need to know the chemical characteristics of waste streams released from power plants to comply with environmental regulations, design pollution control devices, and estimate impacts. Companies also need to compare emissions from plants with different configurations to make decisions on plant construction and inform fuel purchasing decisions.

**Approach**

The Power Plant Integrated Systems Chemical Emissions Studies (PISCES) Database is a comprehensive, multimedia online database containing information on the concentration and fate of chemical substances in power plant process and discharge streams. All of the data entered into the PISCES Database are critically reviewed and quality ranked. This project provides easily accessible data of known quality that can be used for many purposes, including TRI reporting, permitting, design of environmental controls, and fate and transport evaluation. In 2012, this project will continue migration of the database to a new platform. Also, continued addition of new data provides for an up-to-date and comprehensive set of data on solid, liquid, and gas process streams at power plants.

**Impact**

- Provides data to respond to regulatory requirements
- Informs pollution control design and management strategies and fuel purchasing decisions for power plants
How to Apply Results

The PISCES database is web based and is available online 24 hours per day. The desired data can be retrieved and used by member company personnel (such as environmental affairs and plant design and operations personnel) for a variety of purposes, including meeting regulatory needs and designing or enhancing plant operations. EPRI provides specific information-access assistance to members if needed.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>PISCES database: Work will continue on PISCES database upgrades, data entry, and maintenance.</td>
<td>12/31/12</td>
<td>Software</td>
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</table>
Occupational Health and Safety - Program 62

Program Overview

Program Description
Workplace injuries affect employee health, productivity, and job satisfaction and increase the cost of doing business. Efforts to reduce injuries and illnesses, medical costs, and losses in productivity and to improve overall morale are a critical part of electric power company operations. Within the electric power industry, typical risks result from poor ergonomic design in equipment. Misguided procedures and long-term or repetitive exposure to various physical agents continue to be a source of injury or illness. Companies must develop strategies for compliance with worker health and safety requirements for reliable, uninterrupted delivery of electricity to customers, in addition to strategies for meeting exposure standards. The U.S. Occupational Safety and Health Administration (OSHA) is anticipated to accelerate its regulatory agenda, which includes injury and illness record keeping, beryllium exposure, and slips, trips, and fall hazards.

The Electric Power Research Institute’s (EPRI) Occupational Health and Safety program provides scientific research needed to make informed decisions about control methods geared toward workplace injury and illness prevention. Products, tools, and design recommendations that emerge from this research help electric power companies maintain safer, healthier work environments and control labor-related costs. The research identifies injury and illness trends, develops cost-effective ergonomic interventions and designs, and addresses critical occupational exposure issues. The program serves as the foundation for occupational health and safety-related work within the electric utility industry.

Research Value
The EPRI Occupational Health and Safety Database is a valuable resource for tracking and benchmarking occupational injury and illness rates and costs. The Database contains more than one million worker-years of information from 18 electric power companies. The Database provides statistically powerful means to analyze injury data, allowing for exposure-specific analysis across the electric utility industry. EPRI is an innovative leader in occupational ergonomics, specializing in addressing the specific needs of the electric power sector. The program develops cost-effective ergonomic interventions for a range of workers and tasks and develops specifications for the ergonomic design of electric power facilities and equipment. The program also investigates occupational exposures that can affect health (for example, exposures to welding fumes and heat stress). Through its occupational health and safety research, EPRI helps the electric power industry develop effective tools for exposure monitoring and implement effective prevention strategies.

Approach
This program delivers research, data, analyses, and expertise that help electric power companies effectively address occupational health and safety issues. The program transfers the knowledge through many avenues:

- The Occupational Health and Safety Database annual report, which compiles information on injury and illness rates and statistical analyses drawn from unique, industry-specific data
- Easy-to-read handbooks and instructive DVDs describing ergonomic interventions and design guidelines
- Presentations on ergonomics to industry, the scientific community, and regulatory agencies
- Representation of the electric utility sector on the advisory council for the National Institute for Occupational Safety and Health's National Occupational Research Agenda
- Reports and peer-reviewed literature on toxic and potentially toxic workplace exposures that provide data for guideline setting by OSHA and for compliance with federal and state regulations
Accomplishments

The program provides timely, reliable, and comprehensive solutions to industry-specific research needs and offers practical implementation guidance. Program accomplishments include:

- improved worker health and safety through reduced workplace injuries (ergonomic solutions reduced strain and sprain injuries among power plant and line workers);
- reduced health care costs, now estimated at potentially millions of dollars per injury case for some injuries for individual electric companies;
- improved productivity and morale in a healthier workforce, as well as improved product quality; and
- the first ergonomic power plant design handbook, a key reference for design engineers.

Current Year Activities

Program R&D for 2012 will focus on refining the injury surveillance database, assessing ergonomic fleet vehicle maintenance and design, assessing ergonomics in new work environments related to renewable energy resources, characterizing occupational exposure to multiple metals in welding fumes and temperature extremes, and developing a comprehensive, industry-specific exposure database. Specific efforts will

- develop ergonomic interventions and design specifications for fleet vehicles to prevent chronic injuries resulting from inefficient design of tasks, tools, and equipment;
- provide accurate, quantitative data and statistical analyses on injury rates and trends and associated costs, including the 2012 Annual Occupational Health and Safety Statistics Report;
- develop descriptive summary reviews to highlight and communicate industry data on specific injury categories and causes (e.g., noise, temperature extremes, shift work);
- minimize the impact of specific occupational health outcomes through clarification of relationships among occurrence rates, occupational exposures, and lifestyle factors; and
- provide relevant scientific data for setting occupational guidelines on exposure to metals in welding fumes (for example, beryllium, hexavalent chromium) and on temperature extremes (for example, heat stress).

Estimated 2012 Program Funding

$1.5M

Program Manager

Gabor Mezei, 650-855-8908, gmezei@epri.com
Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P62.001</td>
<td>Occupational Health and Safety Database</td>
<td>This project produces the Occupational Health and Safety Database, a unique source of detailed, comprehensive, standardized injury and illness rates and statistical analyses specifically for the electricity industry. The database is updated with new information from multiple electric companies on an annual basis. An annual report on major injury trends and costs is prepared from information drawn from the database. The database also helps guide program priorities.</td>
</tr>
<tr>
<td>P62.002</td>
<td>Ergonomics Research</td>
<td>This research determines the role of ergonomic factors in current work task design and in implementation of tools and equipment, and suggests remedial interventions. Results provide impartial information for dealing with costs and complying with ergonomics guidelines and regulatory needs. In 2012, this project will address ergonomics issues related to the purchase, retrofit, operation, and maintenance of fleet vehicles and ergonomics issues in new occupational environments related to renewable energy generation (e.g., wind turbines, solar farms).</td>
</tr>
<tr>
<td>P62.003</td>
<td>Occupational Exposure and Health Studies</td>
<td>This research investigates relationships among injury and illness occurrence rates, lifestyle factors, and workplace exposures (e.g., welding fumes, heat stress, and noise). Exposure characterization and epidemiologic research address occupational and lifestyle factors potentially associated with injuries and illnesses, and statistical analyses of existing occupational exposure and health information provide further insight. Current issues include exposure to metals in welding fumes (e.g., hexavalent chromium, beryllium), heat stress, and noise. Development of a comprehensive exposure database will also contribute to significant cost savings in exposure monitoring by pooling available industrial hygiene data from participating companies.</td>
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P62.001 Occupational Health and Safety Database (101907)

**Key Research Question**

To maintain a healthy workforce, improve productivity, and control health care costs, electric power companies need access to accurate illness and injury incidence rates and cost impacts. For comprehensive databases, the National Academy of Sciences recommends coding of injury/illness data using standardized procedures and precise, consistent descriptions. Only a comprehensive, industry-specific database containing populated standardized fields from multiple companies provides a robust foundation needed for informed preventive measures.

**Approach**

Updated yearly, the Occupational Health and Safety Database (OHSD) is a unique source for detailed, comprehensive, standardized injury and illness rates across the electricity industry. The OHSD also enables monitoring and evaluation of workforce injury and illness trends and provides a basis for identifying high-risk occupations, quantifying costs and lost time, and setting research priorities. In addition, the database is a powerful tool for benchmarking and safety program evaluation for participating companies. The database is the source of information for tailored analyses for individual electric companies, selective descriptive analyses by injury type or cause, and for the Annual Occupational Health and Safety Statistics Report, providing statistical analyses for the electricity industry.
Impact

- Enables medical cost control by identifying injury trends and tracking related costs
- Contributes to reduction of injury and illness rates
- Supports benchmarking and continual injury monitoring
- Provides information for establishing health and safety program priorities and for estimating the impact of prevention programs
- Directs health and safety research
- Aids in assessment of the effectiveness of injury and illness prevention programs

How to Apply Results

Occupational health and safety staff at participating electric companies will use project information and analyses to monitor and control health care costs, improve health and safety programs, and reduce occupational illness and injury rates. Information from this project can also be used to identify health and safety research gaps.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>This technical report continues a series of reports that provide quantitative, detailed injury and illness incidence rates and strategic economic impacts from trends analyses based on information from the EPRI Occupational Health and Safety Database.</td>
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P62.002 Ergonomics Research (102993)

Key Research Question

Musculoskeletal (strain and sprain) injuries currently account for more than 40% of total medical costs for electric power companies. EPRI statistical analyses found that in just four companies, there was a loss of more than 70 full-time-equivalent employees for one full year owing to these injuries. Reduction of injury rates and associated costs depends on prevention of chronic injuries resulting from inefficient design of tasks, tools, and equipment. Evaluation of existing designs and development of ergonomic interventions are essential to strain and sprain injury prevention.

Approach

The aim of this project is to develop specific interventions to prevent chronic injuries resulting from inefficient design of tasks, tools, and equipment. Effective ergonomic interventions can reduce injury rates and associated costs. Research results also provide objective information relevant to compliance with ergonomics guidelines and regulations. In 2012, research will continue to focus on ergonomics issues related to fleet vehicles in the electric power industry and ergonomics issues in new occupational environments related to renewable energy generation (e.g., wind turbines, solar power plants).

Impact

- Provides ergonomic evaluation and intervention that can help companies reduce injury rates and associated costs through prevention
- Helps improve worker job satisfaction and productivity
- Helps ensure compliance with ergonomics guidelines and regulations

How to Apply Results

Application of EPRI ergonomics research results can help prevent chronic injuries among electric industry workers through improved work practices and ergonomically designed tools and equipment. These interventions can also help ensure workforce compliance with ergonomics guidelines and regulations. Results from the fleet
vehicles project can help electric companies prevent vehicle-related injuries associated with ergonomically poor entry and exit design, seating, and access to parts, tools, and equipment. Implementation of ergonomic interventions requires an investment of time and money; however, many recommended interventions are low in cost.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Fleet Process Guidelines for Selection of Fleet Vehicles:</strong> This technical report will</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<tr>
<td>clearly outline the process for specification, selection, and purchase of fleet vehicles</td>
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<td>for use in the electric power industry. The report will include flow charts, decision</td>
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<td>trees, and checklists used to aid departments responsible for fleet vehicle purchase.</td>
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Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Ergonomic Interventions Evaluation:</strong> This peer-reviewed paper will summarize methods</td>
<td>12/31/13</td>
<td>Peer Literature</td>
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<td>used for an assessment of measured results in overhead linemen/women ergonomic work.</td>
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</table>

P62.003 Occupational Exposure and Health Studies (055833)

Key Research Question

Adverse health effects can result from occupational exposure to physical and chemical agents (e.g., heat, noise, beryllium, hexavalent chromium). The updated OSHA regulatory agenda includes—among other issues—an injury and illness prevention program, exposure to beryllium, and walking/working surfaces posing slip, trip, and fall hazards. Occupational exposure to temperature extremes (e.g., heat stress in power plants and in areas with hot climate) continues to result in potential health hazards and loss of productivity.

Approach

Scientific research in this project provides relevant data for setting standards and guidelines and for developing appropriate strategies to comply with OSHA regulations for exposure to metals in welding fumes (such as beryllium and other toxic substances). Expanding previous work on exposure to hexavalent chromium during welding, data on exposure to other metals in welding fumes (e.g., beryllium) will be collected and assembled in a systematic fashion to meet OSHA’s objective data requirement. Air sampling data from multiple electric power companies will be collected and analyzed to determine the potential for overexposure to beryllium and other metals in various work situations. Work to develop an exposure database that captures a wide range of industrywide exposures is also planned and will form the basis of a job-exposure matrix. Specific focus will be placed on the characterization of physical stressors, including heat stress in various work environments, and noise exposure and hearing loss prevention. Future EPRI program work will characterize shift work within electric utilities, assess the degree of maladaptation, and design possible interventions for these workers.

Impact

- Provides knowledge necessary for developing preventive measures to minimize the health impact of environmental exposures
- Helps ensure compliance with exposure standards
- Offers the opportunity to improve worker health, morale, and productivity
• Reduces health-related costs
• Provides information about health risks associated with power plant occupational exposures that can be used to address proposed regulatory limits and to effectively protect and communicate with workers
• Provides a comprehensive exposure database that will contribute to significant cost saving in exposure monitoring by pooling available industrial hygiene data from participating companies

How to Apply Results

Results from this work can be used to assess potential health risks associated with occupational exposures and to develop preventive measures, including appropriate work practices that electric companies can implement. Electric company occupational health and safety staff also will use results to determine compliance with exposure standards. In addition, results may provide input to exposure standard formulation.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Electric Utility Industry Occupational Exposure Database: This exposure database report</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>will identify and include all exposure factors that can be used to inform utility</td>
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<td>professionals, exposure assessment experts, and epidemiologists assessing health and</td>
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<tr>
<td>safety issues related to work near electric facilities. Development of a comprehensive</td>
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<td>exposure database will also contribute to significant cost saving in exposure monitoring</td>
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<td>by pooling available industrial hygiene data from participating companies.</td>
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| Heat Stress in the Electric Utility Industry: A review of the most recent literature on   | 12/31/12                | Technical Report |
| heat stress, with a focus on impacts within the electric utility industry, is planned.    |                         |                  |
| This technical report will identify those occupations, tasks, or locations most likely   |                         |                  |
| at risk of heat stress; review heat stress management practices currently used; and      |                         |                  |
| identify gaps in research.                                                              |                         |                  |

Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Shift Work Among Electric Utility Workers: This technical report summarizes findings from</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
<tr>
<td>a pilot study that monitors human rest and activity cycles and hormone levels to identify</td>
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<tr>
<td>workers who appear maladapted to their shift-work schedule. If maladaptation is present</td>
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<tr>
<td>among electric utility workers, future work should identify possible factors in daily life</td>
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<td>to target intervention methods.</td>
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</table>

| Heat Stress Laboratory and Field Studies: This technical report will describe research on  | 12/31/13                | Technical Report |
| calorimetric laboratory and field studies aimed at quantitatively characterizing heat stress|                         |                  |
| for specific occupations.                                                                 |                         |                  |
Occupational Exposure to Physical Stressors: Intervention and Prevention (072036)

Background, Objectives, and New Learnings

Occupational exposures to physical stressors such as noise are prevalent within the electric utility industry. During 1995-2009, the EPRI Occupational Health and Safety Database, which tracks illness and injury for eighteen member utilities, showed that hearing loss or impairment resulted in 3% of total utility worker injuries. If constantly exposed to noise, workers may experience progressive hearing loss slowly over time, which in turn may affect their ability to perform safely and translate to an indirect number of acute workplace injuries.

Noise-induced hearing loss has been implicated in workplace accidents. Auditory changes are progressive, possibly placing workers at risk for accidents. Traditionally, workers are enrolled in hearing conservation programs after an action level of 85 decibels (dB) is met. Noise surveys capture environments requiring action but are not conducted at multiple time points; consequently, noisy environments may be underestimated. According to published studies in the aluminum industry, annual audiometry data capture hearing loss once it has occurred and the most vulnerable workers actually may fall below the accepted permissible exposure limit. Since opportunities to intervene prior to hearing loss are limited using annual audiometry, data gaps exist for workers who may be just below 85 dB and who may potentially have preventable workplace hearing loss.

Workers may use personal protective gear such as ear muffs and ear plugs that modify exposure; hence, measured ambient or personal exposure levels may not reflect actual exposure. Novel in-ear dosimetry technology—devices that fit like an earplug and measure attenuated noise from within the ear canal—could be used to address worker discomfort and potential exposure modification issues. In addition, the dosimeter could be programmed to advise the worker and/or her/his supervisor when pre-set exposure limits are exceeded. Thus, a worker would get feedback on exposure above that pre-set limit and on her/his daily dose at the end of the shift, both of which could assist in guiding personal protective equipment use.

Project Approach and Summary

In this project, research will evaluate the dosimeter using built-in feedback systems as an intervention method for preventing noise-induced hearing loss and will examine the relationship between noise levels and risk of acute occupational injury. Results will provide quantitative noise dosimetry, an assessment of the dosimeter as an intervention method and a potential leading indicator for noise-induced hearing loss and other injuries. By the end of the project, results should provide a method for assessing a state-of-the-art intervention method and an assessment of noise-induced hearing loss as a leading indicator for a number of acute workplace injuries.

Benefits

Workplace injuries are traditionally targeted using interventions proximal to the acute event, such as behavioral factors, rather than distal factors, such as other exposures. Furthermore, hearing loss is often attributed to workers’ lack of compliance, lack of supervision, or inappropriate use of personal protective equipment. This project assesses a potential leading indicator, not only of hearing loss, but also of workplace injuries. The developed intervention, if successfully applied, may result in reduced frequency of hearing loss and occurrence of acute injuries in the workforce, with associated potential cost savings and improved worker health and performance.

Occupational hygienists, managers, and safety specialists within electric utilities may use the in-ear dosimeter as a means to train their workers on the effective use of hearing protection and to clarify whether workplace noise is a contributor to other occupational injuries. Additional benefits derived from the work include an improved method to comply with OSHA “Employee Notification” requirements (1910.95).
T&D and ROW Environmental Issues - Program 51

Program Overview

Program Description
As the nation’s power grid is upgraded and expanded, safe and reliable operation takes on heightened importance. As the electric transmission and distribution (T&D) infrastructure expands and ages and new rights-of-way (ROW) standards are developed, power companies need to manage human health risks and minimize environmental impacts from and species interaction with power delivery systems. System components, such as service centers, substations, and cables, face issues related to spills, runoff, and cleanups, and life-cycle decision making is a critical route to improved environmental performance. Environmentally acceptable options are needed for selecting and managing utility poles and dielectric fluids, designing facilities, and remediating contamination. Efficient, cost-effective ROW vegetation management and transmission line siting are increasingly important as the Federal Energy Regulatory Commission (FERC) and the North American Electric Reliability Corporation (NERC) develop new reliability standards. In addition, power companies need to reduce avian interactions with generation and T&D facilities and protect sensitive species and habitats during ROW construction and maintenance while recognizing opportunities to optimize ecological assets on new and existing ROWs.

The Electric Power Research Institute’s (EPRI’s) T&D and ROW Environmental Issues program delivers information, tools, and methods for preventing, characterizing, and remediating soil and water contamination at T&D facilities, as well as for designing and retrofitting T&D facilities. Data and products from the program support development of scientifically sound regulations and cleanup standards for chemicals associated with T&D and ROW facilities and operations, as well as providing engineering, science, and business tools to aid in their management. The program also provides balanced, cost-effective solutions for addressing economic and environmental challenges with siting, developing, managing, and upgrading T&D ROWs. Innovative tools, practical guidance, and state-of-the-art information help companies control ROW costs and improve service reliability while protecting natural resources and addressing public, regulatory, and other stakeholder concerns.

Research Value
Program research has documented savings of $10 million per year industrywide for used oil management, $1.5 billion per year for management of creosote and pentachlorophenol utility poles as nonhazardous waste, and $500,000 at a single site by demonstration of the true risk of a mineral oil spill. The program also helped save one company $1 million in spill prevention, control, and countermeasure (SPCC) regulatory compliance costs. Program research also expedites transmission line siting and ensures system reliability by addressing ecological issues associated with NERC vegetation management standards, reducing ROW maintenance costs, and enhancing ecological value through Integrated Vegetation Management (IVM). The program also improves a utility’s ability to prevent and assess bird strike impacts, enhances ecosystems along T&D ROWs, and provides materials to help companies communicate with regulators and address public concerns. This program provides

- scientific information and data to help power companies make optimal decisions on T&D ROW equipment choices and remedial approaches;
- characterization information on substances related to environmental and human health risk, and strategies to reduce financial risk and operations and management costs;
- constructive engagement on federal oversight of transmission vegetation management, and information for regulatory development; and
- opportunities for proactive environmental management to decrease potential for outages and fines, and shorter time frames for siting new transmission lines.
Approach
This program addresses environmental challenges at substations, service centers, and T&D ROWs with options assessment, fate and transport studies, and remedial approaches. The program facilitates communications with stakeholders through data and life-cycle studies. It examines a growing societal focus on sustainability by looking at issues such as the large resource represented by out-of-service utility poles. The program conducts field studies, best-practice surveys, risk assessments, workshops, and technology development and demonstration projects. This program delivers

- software tools for advanced spill simulation to examine environmental impacts of leaks such as oil spills and to support discussions with regulators;
- pilot tests to expand remediation options for spills and leaching of substances such as arsenic;
- decision tools that explore management options for selection of wood poles and remediation of contaminated sites;
- collaboration with other industry groups such as the Avian Power Line Interaction Committee, International Society of Arboriculture, Utility Arborists Association, NERC, and federal agencies such as FERC and the U.S. Fish and Wildlife Service;
- continuing support for the international symposia on environmental concerns in ROW management;
- IVM field assessments of transmission vegetation management practices to aid utilities in reducing vegetation management costs while addressing environmental and sustainability goals;
- long-term vegetation management field studies to reduce vegetation management costs and address issues identified during IVM field assessments; and
- development of innovative tools to reduce avian and other animal interactions at utility facilities.

Accomplishments
This program provides data, tools, and information that deepen understanding of the environmental consequences of actions, including operations and remediation. Using sound scientific information from this program, companies have

- negotiated cleanup endpoints for substations contaminated with dielectric fluids or arsenic that represent acceptable risk and lower cost;
- designed substation retrofit plans acceptable to regulators that minimize risk and reduce costs;
- conducted efficient management of materials and equipment as nonhazardous, where appropriate, at the end of their useful lifetimes;
- benefited from commercialization and deployment of a Bird Strike Indicator at utility sites to clarify operational impacts and to reduce financial and criminal liabilities due to avian interactions with facilities;
- derived value from analysis of NERC vegetation management standards for compliance with the standards; and
- derived value from guidance and informational sources for addressing invasive species on transmission ROWs.

Current Year Activities
Program R&D for 2012 will focus on minimizing and managing environmental and human health risks from operation of the power delivery system and on providing information to expedite transmission line siting, reduce transmission outages, and minimize adverse avian interactions. Specific efforts will include

- improving approaches to identifying PCB-containing equipment and exploring associated risks,
- identifying and developing an assessment of environmental and human health risk from aging T&D infrastructure,
- evaluating aspects of design and operation of green substations,
- investigating options for control of stormwater runoff from T&D facilities,
- continuing to examine the environmental performance of wood poles,
- developing information to assist utilities in understanding and mitigating avian interaction with utility facilities,
- developing information to assist utilities in reducing risk to workers during herbicide application, and
- developing information to assist utilities in upgrading and siting of transmission lines.

**Estimated 2012 Program Funding**

$1.25M

**Program Manager**

Mary Mclearn, 650-855-2487, mmclearn@epri.com

### Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P51.001</td>
<td>PCBs: Mitigation and Remediation</td>
<td>This project develops options for identification of equipment containing PCBs, as well as data and analyses to inform regulations and decisions involving PCBs.</td>
</tr>
<tr>
<td>P51.002</td>
<td>Oils: Spill Control, Countermeasures, and Response</td>
<td>This project supports prevention, management, and remediation of leaks and spills of dielectric fluids and stormwater runoff through improved facility design and operation, thereby reducing operational, financial, environmental, and human health risks.</td>
</tr>
<tr>
<td>P51.003</td>
<td>Aging T&amp;D Infrastructure -- Environmental Risk Management: Relative Risk Model Development</td>
<td>This project develops data and tools to proactively manage environmental and human health risks from incidents resulting from aging T&amp;D infrastructure.</td>
</tr>
<tr>
<td>P51.004</td>
<td>Utility Poles: Assessment and Impact</td>
<td>This project develops approaches and provides data to help companies manage poles across the pole life cycle, using practices that ensure engineering performance, manage costs, and protect the environment and human health.</td>
</tr>
<tr>
<td>P51.005</td>
<td>Integrated Vegetation Management (IVM) and Inspection Techniques</td>
<td>This project develops information aimed at containing and reducing long-term vegetation management costs for T&amp;D facilities while addressing reliability, regulatory, and environmental concerns.</td>
</tr>
<tr>
<td>P51.006</td>
<td>Transmission Siting Integrating National Corridors and NERC Compliance Requirements</td>
<td>This project develops a guide to assist system planners, line designers, environmentalists and route selectors in the understanding of the technical basis for various regulatory requirements that must be met in justifying and siting new transmission lines.</td>
</tr>
<tr>
<td>P51.007</td>
<td>Avian and Animal Interactions with Utility Facilities</td>
<td>This project develops information and tools to mitigate avian and other wildlife interactions with utility facilities to reduce outages and potential takes under federal law.</td>
</tr>
</tbody>
</table>
P51.001 PCBs: Mitigation and Remediation (100778)

**Key Research Question**
PCB-containing dielectric fluids were used extensively in electrical equipment until their use was banned in the late 1970s. Utility companies are continuing to remove equipment that contains PCBs. This equipment can be difficult to identify, so strategies for identification and removal are needed. Some regulators and risk assessors are focusing on individual PCB congeners, especially the dioxin-like congeners, and may be requiring congener-specific monitoring at some sites. Information about congener-specific monitoring and risk assessment will be needed. Implications of new regulations must be understood.

**Approach**
This project aims to improve management and facilitate removal of equipment containing PCBs by developing strategies to identify PCB-containing equipment, to reduce compliance costs by providing information to facilitate communication with all stakeholder groups, and to reduce costs as regulations continue to develop and as PCB spills continue to be discovered and addressed. This project will

- improve identification of equipment containing PCBs, and
- track and analyze regulatory and risk issues related to PCB congeners.

**Impact**
- Improves management of PCB removal programs by developing strategies for identification of equipment containing PCBs
- Reduces compliance costs by providing information on actual PCB species and their potential impact and health risk
- Helps clarify and reduce risks related to PCB exposures
- Improves risk assessment and facilitates communication with all stakeholder groups
- Saves electrical equipment owners tens of thousands to millions of dollars as regulations continue to develop and PCB spills continue to be discovered and addressed

**How to Apply Results**
Scientists and engineers will use strategies for identification of equipment containing PCBs to facilitate removal. They will use the results of congener-based studies to inform development of regulations, assess sites, simulate migration, negotiate site cleanup endpoints, and communicate with all stakeholder groups, including policymakers, other researchers, trade press, media, and the public. As new information, products, and tools are developed, program participants will have first access and will apply results to environmental decisions. Working with participating member company scientists and engineers, EPRI staff may communicate directly with regulators or with members of the public. External stakeholders, including regulators and members of the public, will use the results as part of environmental decision making and rulemaking.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Identification of Transformers Containing PCBs:</strong> This technical update will correlate ranges of PCB concentrations with information commonly found on transformer faceplates and related records.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Impacts of Regulating PCBs as Dioxin-like Compounds:</strong> This white paper will analyze and compare the expected requirements for dioxin-like PCBs with current requirements for Aroclor PCBs.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
</tbody>
</table>
P51.002 Oils: Spill Control, Countermeasures, and Response (Q55817)

**Key Research Question**

Routine operation of T&D facilities, such as substations and service centers, may result in leaks, spills, or fires, as well as stormwater runoff, with potential human health and environmental impacts. Prevention requires good facility design and construction. Compliance and protection require good understanding of the risk of an incident and the toxicity of the fluids involved. New, greener fluids and designs are emerging that may reduce impacts in the future. Through conceptual, laboratory, and field projects, EPRI researchers study facility design, as well as chemical composition, environmental fate and transport, and risks from dielectric fluids.

**Approach**

This work aims to improve facility design, streamline compliance, and reduce costs by addressing regulatory and public concerns, evaluating substation design and retrofit options, and protecting groundwater and soil through improved detection and location of leaks and mitigation of impacts of stormwater runoff. The project has demonstrated to one state agency that non-PCB capacitor fluids could be managed as synthetic oils, saving hundreds of thousands of dollars for one company. The project will

- update EPRI’s Mineral Oil Spill Evaluation System (MOSES) for simulating oil spills and facilitating substation retrofit and design,
- consider and assess improved approaches to spill and stormwater control, and
- improve designs for substations to provide enhanced health and environmental protection and work toward "green" certification.

**Impact**

- Streamlines spill prevention and countermeasure compliance by developing information and tools to address regulatory and public concerns
- Protects groundwater and soil from accidental leaks and spills as well as stormwater runoff
- Demonstrated to one state agency that non-PCB capacitor fluids could be managed as synthetic oils, saving hundreds of thousands of dollars for one company on handling and disposal

**How to Apply Results**

Facility engineers and designers will use results of green substation studies to improve substation features toward improved environmental performance. Scientists and engineers will use the results of fate and transport studies on dielectric fluids to inform development of regulations, assess sites, simulate migration, negotiate site cleanup endpoints, detect and locate leaks, and communicate with all stakeholder groups, including regulators and members of the public. Scientists and engineers will use the results of remediation studies to prepare and implement action plans for contaminated sites. As new information, products, and tools are developed, program participants will have first access and will apply results to environmental decisions. In addition, EPRI will facilitate broader use and awareness of the results by briefing key stakeholders, including policymakers and
other researchers; developing materials for the public/trade press/media; organizing design workshops; and presenting at meetings/seminars.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td>Green Substations - Alternate Transformer Oil Containment:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>The work will investigate new options for on-site secondary</td>
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<tr>
<td>containment for oil spills from transformers and other electrical</td>
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<td>equipment at substations. Manufacturer-supplied systems and</td>
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<tr>
<td>pressure-relief systems may also be investigated.</td>
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<tr>
<td>MOSES-MP Version 4: This activity will present the MOSES-MP</td>
<td>12/31/12</td>
<td>Technical</td>
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<tr>
<td>Version 4 software and train users on its use.</td>
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<td>Resource</td>
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<tr>
<td>MOSES-MP Version 4: This work will produce version 4 of the</td>
<td>12/31/12</td>
<td>Software</td>
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<tr>
<td>MOSES-MP software, offering enhanced features and compatibility</td>
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<td>with current operating systems.</td>
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Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Green Substations - LEED Certification for Substations:</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td>This work will explore requirements for LEED certification for</td>
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<td>substations.</td>
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<tr>
<td>Stormwater Control at T&amp;D Facilities: This research will assess</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>improved approaches to stormwater control at T&amp;D facilities</td>
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<td>such as substations, service centers, and ROWs.</td>
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P51.003 Aging T&D Infrastructure -- Environmental Risk Management: Relative Risk Model Development (069220)

Key Research Question
As the electric transmission and distribution infrastructure grows older, risks of leaks and spills of fuels, dielectric fluids, and other liquids or gases may increase, resulting in increased financial risk to companies as well as increased risk to human health and the environment. Companies need to understand the risks and vulnerabilities, and they need approaches to identifying and assessing those risks and vulnerabilities.

Approach
This project develops a proactive approach to managing environmental and human health risks from aging infrastructure by improving understanding of probabilities and ramifications of incidents. This project will

- identify potential contaminants from leaks in the T&D infrastructure
- identify likelihood of incidents,
- assess environmental and human health risks from these contaminants,
- assess related financial risks, and
- identify and develop methods to prioritize actions to minimize risks.

The Relative Risk Model will be developed under this base project. Detailed case studies will be conducted with individual companies with supplemental funding. The generic results of the case studies will be incorporated into the model but not linked to any company. Program funders will receive the model and a case study summary. Each supplemental funder will receive a detailed report on its case study.
Impact

- Develops tools to evaluate relative risks, prioritize actions, and thereby mitigate negative outcomes to human health and the environment from aging T&D infrastructure
- Reduces costs and resource use for cleanups and litigation

How to Apply Results

Scientists, engineers, and asset managers will use the results of aging infrastructure risk studies to prioritize actions to repair and replace equipment in order to proactively prevent or minimize environmental impacts. The Relative Risk Model may be used to rank equipment in one category, such as transformers, or to compare facilities such as substations.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Relative Risk Model for Environmental and Human Health Risk from Aging Infrastructure:</td>
<td>12/31/12</td>
<td>Software</td>
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<tr>
<td>The model will streamline estimation and comparison of risks to facilitate development of</td>
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<td>action plans.</td>
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<tr>
<td>Environmental and Human Health Risk from Aging Infrastructure: Workshop: This workshop</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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<tr>
<td>will demonstrate the Relative Risk Model and train users in its use.</td>
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Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Environmental and Human Health Risk from Aging Infrastructure: Case Study Summary: This</td>
<td>12/31/13</td>
<td>Technical</td>
</tr>
<tr>
<td>technical update will document applications of the Relative Risk Model but include no data</td>
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<td>Update</td>
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<td>proprietary to the participating companies.</td>
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P51.004 Utility Poles: Assessment and Impact (100315)

Key Research Question

Poles are a huge and valuable asset of a utility company. Companies need to manage poles across the pole life cycle with practices that ensure engineering performance, manage costs, and protect the environment and human health. This process begins with selection of the optimal pole for each setting, continues through careful use, and ends with final disposition that recognizes the asset value and minimizes ongoing risk.

Improved specification of new and replacement poles allows companies to better manage operational, financial, environmental, and human health risk. Optimal processes for prevention of leaching reduce environmental and human health impacts from pole treatments. Information on chlorophenols, dioxins, metals, and supplemental treatment chemicals is critical to obtaining science-based, cost-effective regulatory decisions, as well as supporting optimal business decisions by pole owners. Alternatives to landfilling and giveaway programs for treated wood poles are essential to help companies manage risks and recover the huge resource represented by wood poles at the end of their useful life.

Demonstrating low risk for treated wood can save owners billions of dollars by reducing disposal costs and facilitating recycling. Assessing nonwood alternatives can offer companies lower-risk, reasonable-cost options in some settings.
Approach
This project aims to reduce costs and minimize human health and ecological risks from poles across their life cycle, to address regulatory and public concerns about poles, and to scientifically substantiate the ongoing $1.5 billion-per-year cost savings from the nonhazardous waste designation for poles. The project will

- conduct long-term fate and transport studies of wood treatment chemicals,
- assess both nontreated wood and nonwood alternatives to treated wood poles as these alternatives are proposed and become commercially available, and
- explore options for managing poles, including storage, use, recycling, and reuse of poles with minimal health and environmental impacts.

Impact
- Reduces costs and minimizes human health and ecological risks from poles
- Informs regulatory and public concerns about pole use
- Saves the industry $1.5 billion per year in ongoing cost savings as a result of the nonhazardous waste designation for poles

How to Apply Results
Member company engineers and scientists need to read, understand, and disseminate the results to key stakeholders, both inside and outside utility companies. Internal stakeholders—scientists, engineers, purchasing agents, and others—will incorporate the information into product specifications, operations and management procedures, and waste management decisions, as well as environmental policies and procedures and communications programs. External stakeholders, including regulators and members of the public, will use the results as part of environmental decision making and rulemaking. In addition, EPRI will facilitate broader use and awareness of the results by briefing key stakeholders, including policymakers and other researchers; developing materials for the public/trade press/media; and presenting at meetings/seminars.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Poles Working Group: This workshop provides a forum for discussion of issues related to poles across their life cycles, including acquisition, use, and ultimate disposition by reuse, recycle, or disposal.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Alternatives to Treated Wood for Utility Poles: This product will continue to provide current information on the practicality and availability of options for poles as those options emerge.</td>
<td>06/30/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Migration of Treatment Chemicals from Treated Wood Poles: This product will update data tables and graphs demonstrating the migration of pentachlorophenol, creosote, chromated copper arsenate, and other treatment chemicals from poles.</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
P51.005 Integrated Vegetation Management (IVM) and Inspection Techniques (101938)

Key Research Question
All ROWs are managed with the general goal of providing safe and reliable transport of electricity. ROW managers strive to meet these goals by developing low-growing vegetation that persists over the long term. For most ROW managers, active management is required to create desired vegetation and related environmental conditions. ROW vegetation management represents a major cost for the industry, with individual company costs in the range of $5–$20 million per year. Containing and lowering these costs, while maintaining high reliability and enhancing environmental productivity, are important to competitive success of the company and to environmental stewardship.

Approach
This project focuses on providing information and inspection tools to ROW managers for the cost-effective management of vegetation, which is the largest recurring expenditure for ROWs. The project will

- conduct IVM field research and utility assessments, leading to an industry certification program for transmission ROWs;
- assess the impact of NERC vegetation management standards on transmission IVM and ROW ecology;
- assess the effectiveness of nonherbicide alternatives for vegetation management on transmission ROWs;
- identify and document all currently available inspection technologies that are being utilized by and offered to utilities; and
- provide information and tools to reduce outages on the distribution system

Impact
- Provides practical IVM guidelines reflecting the latest field research
- Provides information to assist utilities in addressing NERC mandatory vegetation standards
- Reduces vegetation management costs and vegetation-related outages (IVM can reduce vegetation management costs by up to half once fully implemented)
- Addresses environmental ROW goals
- Enhances corporate environmental stewardship goals

How to Apply Results
Results from this project will be useful to utility vegetation management and environmental departments. Vegetation managers can apply the information to reduce the cost of vegetation management and the frequency of outages on T&D systems. Environmental managers, in concert with vegetation managers, can apply the information to develop company stewardship goals. It is incumbent upon members to apply the results to meet internal and external needs. The public will benefit from a more sustainable environment along T&D ROWs.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tr>
<td>Safety Manual for Contractor Herbicide Use: Observations during IVM assessments show that utility contractors may not be fully compliant with herbicide label requirements. This manual will provide guidance on improving the safe use of herbicides commonly used to control vegetation along transmission ROWs.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Current Vegetation Inspection Practices, Tools and Technologies: This report will document current vegetation inspection practices, tools, and technologies, including utility experience.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Cost-Effectiveness of Different Non-herbicide and Herbicide Alternatives for Treating Transmission Rights-of-Way Vegetation: This research will focus on the development of information to support decisions on the selection of treatment options for the control of vegetation along transmission ROWs and to communicate to stakeholders the bases for treatment option decisions.</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Current Vegetation Inspection Practices Including Utility Experience: This research will focus on the development of information to support decisions on the selection of treatment options for the control of vegetation along transmission ROWs and to communicate to stakeholders the bases for treatment option decisions.</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Report Documenting New Tools and Emerging Technologies (draft): This report will document existing and innovative inspection practices, tools, and technologies and will document utility experience, if any.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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</table>

P51.006 Transmission Siting Integrating National Corridors and NERC Compliance Requirements (069222)

Key Research Question

Sittings of transmission lines are increasingly important as the Federal Energy Regulatory Commission (FERC) and the North American Electric Reliability Corporation (NERC) develop new standards. Transmission line siting is complex. In National Interest Electric Transmission Corridors, the process follows FERC guidelines. Outside of these areas, the siting process follows state guidelines. In either case, a comprehensive understanding of practical alternatives is essential to acquiring any transmission facilities permit, especially for the siting of a new transmission line. The applicant must demonstrate due diligence in justifying the new line as the best choice when compared to alternatives such as upgrading or uprating existing lines, use of more compact less visually-intrusive line designs, additional utilization of existing corridors, and increased use of underground transmission cables.

As described in the FERC Permit Process, eminent domain proceedings are not the preferred method of obtaining right-of-way. The permitting process is rather one of convincing the public through meetings and education. This approach requires an in-depth understanding of the primary technical issues by everyone involved in the siting procedures and is crucial in obtaining permits from State or Federal regulators. This project develops a guide to assist system planners, line designers, environmentalists and route selectors in the understanding of the technical basis for various regulatory requirements that must be met in justifying and siting new transmission lines.

Approach

The project involves studying the major challenges involved in the siting of new lines, and in identifying the range of mitigating measures that can be applied. It will cover the following research activities:

- Review available regulatory documents and requirements for the justification and siting of new transmission lines.
- Identify underlying technical issues that are involved and prepare a list of topics to be explored.
- Investigate each topic with an emphasis on those issues where the various technical disciplines involved in justifying the need for new lines, designing lines that allow adequate power flow while minimizing visual impact, and meeting the myriad regulations and standards intended to minimize the impact on wildlife and plant growth.
• Compare key technical issues involving state versus federal rules on wildlife and on electric and magnetic fields.
• Study and interpret NERC regulations on equipment and circuit ratings

The research findings will be presented in seminars and a guide will be prepared for members’ use in ensuring compliance with National and NERC siting and corridor requirements. The guide will also document several case studies on recent transmission sitings. In particular, the successful siting of a 138kV line and a more complex EHV line. The case studies will demonstrate the various technical viewpoints involved in new line siting projects when meeting environmental, power system, and line design limitations. By explaining the basic challenges, tools, and needs of the others, the case studies will provide members with a broad overview of the process.

Impact

The workshop and documentation will allow each stakeholder group within a company involved in new line siting projects to understand and address the major issues faced in successfully meeting environmental, power system, and line design limitations.

The technical report provides guidance to the various personnel involved in siting, designing, and justifying new lines to find an approach that gains public and regulatory acceptance quickly, with a minimum of cost and delay.

How to Apply Results

The useful and practical information developed in this project will allow system planning, line design, and environmental engineers and scientists to understand and explain the need for new transmission lines and obtain approval for the proposed route that it must follow. The information developed will be useful in the preparation and justification of any license application for a new transmission line or for modification of existing lines. The information will also be useful in addressing enquiries that may arise during the environmental licensing process, ensuring that regulatory requirements are met and that all mitigating measures are evaluated in a systematic and effective manner.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Understanding the Economic and Environmental Challenges of Transmission Lines: The feasibility of adopting available technologies to alleviate public concerns about overhead lines will be discussed. The advantages and disadvantages of each technology will be presented and compared. The investigations will continue into following years.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td>Economic and Environmental Challenges of Transmission Lines - An Engineering Perspective: Various options that are available to address the major public concerns about overhead lines will be presented and discussed. The advantages and disadvantages of these options will be compared. Options include technology, design, and material for overhead lines. Topics to be discussed will be results from the current year’s research and will be included in the technical update.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td>Successful Transmission Line Sittings: The workshop presents and discusses case studies on successful transmission sitings that integrate compliance with National and NERC regulations.</td>
<td>12/31/13</td>
<td>Technical Resource</td>
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</table>
### Draft Guide for Compliance with National and NERC Siting and Corridor Requirements

A draft guide assisting members in siting transmission lines successfully will be prepared. The guide may provide various options that are available to address major public concerns about overhead lines. Comparisons of the advantages and disadvantages of these options may be included. Options include technology, design, and material for overhead lines.

**Planned Completion Date:** 12/31/13

**Product Type:** Technical Update

### Guide for Successful Transmission Line Sittings

The workshop presents and discusses the final guide that assists members in siting transmission lines successfully.

**Planned Completion Date:** 12/31/14

**Product Type:** Technical Resource

### An Engineering Guide for Compliance with National and NERC Siting and Corridor Requirements

The guide assisting members in siting transmission lines successfully will be prepared. The guide may provide various options that are available to address major public concerns about overhead lines. Comparisons of the advantages and disadvantages of these options may be included. Options include technology, design, and material for overhead lines.

**Planned Completion Date:** 12/31/14

**Product Type:** Technical Report

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### P51.007 Avian and Animal Interactions with Utility Facilities (101940)

#### Key Research Question

Birds and other wildlife interact with power structures in many ways. Some structures (towers, poles, stacks) and associated ROW habitats can provide favorable sites for bird nesting, roosting, and foraging and for hunting activities for a wide variety of bird and other animal species, without affecting operations. At the same time, birds are at risk from potential interactions with these structures, including collision with wires and towers, and birds and other wildlife can be subject to electrocution (transformers, conductor configurations). These and other interactions can result in disruption of service and cause negative effects on bird and other wildlife populations. Adverse effects on certain bird species, such as electrocutions of eagles, may result in fines and penalties. Proactive planning can foster environmental stewardship and reduce adverse impacts on avian and other wildlife populations.

#### Approach

This project provides information to improve understanding of avian and other wildlife interactions with utility facilities and how to mitigate those interactions. The project will

- investigate avian vision perception to develop more-effective mitigation devices,
- provide information to reduce bird and other wildlife interactions with utility facilities, and
- develop training material on avian interactions and mitigation approaches.

#### Impact

- Reduces electrical outages
- Determines causes of interactions of birds and animals with utility facilities
- Evaluates the efficacy of mitigation devices
- Reduces liability under several federal laws
- Reduces impacts on avian and animal populations

#### How to Apply Results

Results from this project will be useful to utility environmental and power delivery departments to reduce outages and advance stewardship goals for the protection of birds and other wildlife populations.
### 2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Avian Vision Perception:</strong> This report will summarize the distribution and spectral properties of retinal oil droplets in the eider (<em>Somateria</em> spp, <em>Polysticta stelleri</em>), whooping crane (<em>Grus americana</em>), and California condor (<em>Gymnogyps californianus</em>). This information can be used to estimate the spectral sensitivity of these birds with the objective of developing visual diverters for power lines.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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| **Database on Animal Interaction Products (update):** This product will provide updated information on animal interaction products and vendors in an easily accessible way. | 12/31/12 | Software |

### Future Year Products

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<tr>
<td><strong>Reliability-Centered Maintenance (RCM) and Avian Protection:</strong> Reliability-Centered Maintenance (RCM) provides a structured decision-making process for completing an assessment of maintenance needs focused on preserving the reliability of system function. This work will build on prior work to address how avian outages, including avian protection, can be incorporated as part of the RCM process for the distribution system.</td>
<td>12/31/13</td>
<td>Technical Report</td>
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</table>

| **DVD on Avian Interactions with Distribution Assets:** This product will be a training and resource DVD highlighting how bird outages occur and approaches for mitigation. | 12/31/13 | Technical Resource |
Supplemental Projects

Aging T&D Infrastructure - Environmental Risk Management (067694)

Background, Objectives, and New Learnings
As the infrastructure for the transmission and distribution of electricity grows older, risks to human health and the environment from leaks and spills of fuels, dielectric fluids, and other liquids may increase, resulting in increased financial risk to power companies. The utility industry needs to understand risks and vulnerabilities from aging infrastructure, and it needs approaches to identifying and assessing those risks and vulnerabilities, as well as to prioritizing actions to mitigate those risks. This project will help companies to proactively assess risk to allow prioritization of resources for repair and replacement before incidents occur.

The project addresses this question: how can a utility estimate, analyze, and prioritize its risk from aging infrastructure? The project is developing a Relative Risk Model for assessing aging electrical equipment that will integrate information on components, potential for releases, migration of released materials, environmental settings, toxicology, environmental fate and effects, and financial implications. The model can facilitate evaluation of release scenarios with the highest potential for environmental and health impacts. The utility conducting the analysis can benefit by being able to proactively address its greatest risks, conducting repair and replacement activities before spills, explosions, and other incidents take place. The public can benefit from increased reliability of the electric system (fewer interruptions) and from decreased impacts to human health and the environment (fewer incidents).

Project Approach and Summary
EPRI is developing a conceptual Relative Risk Model and is populating it with available data on components, potential for releases, migration of released materials, environmental settings, toxicology, environmental fate and effects, and financial implications. Through case study applications with individual companies, EPRI will improve and test the model. Participating companies will gain the results of the case study assessments, which they can use to move forward with repair and replacement of vulnerable equipment.

The Relative Risk Model is being developed with base funding. Detailed case studies will be conducted with individual companies with supplemental funding. The generic results of the case studies will be incorporated into the model but not linked to any company. Program funders will be entitled to receive the model and a case study summary. Each supplemental funder will receive a detailed report on its case study, as well as the model and a case study summary.

Benefits
Benefits of assessing risks include improved decision making, cost avoidance for contamination and resulting impact that do not occur, cost reduction for remediation that is limited in scope, and substantial public benefit from protection of human health and the environment.
Electric and Magnetic Fields and Radio-Frequency Health Assessment and Safety - Program 60

Program Overview

Program Description
Timely implementation of new transmission and distribution (T&D) projects will take on heightened importance as the power grid is expanded, upgraded, and modernized and as it integrates smart grid technology and remotely located renewable energy resources. Large-scale introduction of electric vehicles and the associated charging infrastructure will also require significant investment in new grid infrastructure. New T&D construction and capacity upgrades, and expanding smart grid technology and its reliance on two-way wireless communication, can create public concern about possible human health risks from electric and magnetic field (EMF) and radio-frequency (RF) exposures. Such concerns can lead to lengthy delays and possibly cause regulatory decisions that affect project schedules and costs. At the same time, revisions to guidelines for public and worker EMF and RF exposures could result in altered exposure limits. Over the past 5 to 10 years, electric companies have addressed concerns about RF exposure from antennas installed on grid infrastructure and have adopted practices for compliance with the Federal Communications Commission exposure limits. These issues require information and education for the general public and safety awareness training for electric company workers. Further communication is necessary to help inform various constituencies about the distinction between power frequency and RF, the issues unique to each, and current knowledge on relevant health issues.

The Electric and Magnetic Fields and Radio-Frequency Health Assessment and Safety program helps electric power companies address EMF and RF exposures and health issues. Program research and staff scientific expertise contribute to the body of scientific knowledge, better enabling accurate health risk evaluations and informing exposure guideline development. The program’s commitment to research and public communication on EMF and RF health and safety questions responds to a societal need for information.

Research Value
This research supports electric companies with ongoing or proposed T&D projects by providing timely, state-of-the-science information for improved risk communication and issue management. The program delivers research aimed at resolving high-priority EMF and RF health questions and provides input for science-based exposure guidelines to address worker and public safety. EPRI expertise and research results also contribute to risk assessments and other activities that inform EMF policy. The program’s RF safety research contributes to accurate RF exposure assessment, enhances worker safety, and facilitates compliance with RF safety regulations. The program is also aided by a blue-ribbon scientific advisory committee composed of leading independent experts in various disciplines including medicine, epidemiology and statistics, and engineering. In addition, the program maintains an active public communications effort, providing accurate information on EMF and RF topics.

Approach
This program provides research, information, analyses, and expertise that help electric companies, regulators, and society address residential and occupational EMF and RF health and safety issues. This program delivers

- timely, reliable EMF and RF research results, including communication materials, relevant background information, and analyses of key external studies;
- publicly accessible, up-to-date information on EMF and RF research, health risk evaluations, and regulatory actions;
- experimental and epidemiologic research investigating high-priority residential and occupational EMF and RF health and safety questions;
- EMFWorkstation software for modeling T&D infrastructure EMF in residential and occupational settings;
• EMF and RF exposure characterization research and exposure assessment software; and
• educational materials, including instructional EMF/RF DVDs, tutorials, and RF safety awareness training.

Accomplishments
Through peer-reviewed scientific publications, presentations at scientific meetings and seminars, and participation in scientific and technical advisory panels, the program staff have an international reputation for rigorous, independent, credible scientific research. EMF/RF issue managers at member companies report that supporting EPRI EMF research is in itself an appropriate response to public concern.

• Program research results and information can avoid unnecessary costs or delays by helping issue managers address public and worker concerns about EMF/RF, take appropriate steps to ensure health and safety, and provide EMF characterization information for project regulatory applications, including environmental impact statements or assessments.
• Scientific input contributes to accurate EMF health risk evaluations and appropriate exposure guideline development, domestically and internationally.
• EPRI software and instrumentation are essential for characterizing residential and occupational EMF/RF.
• RF safety information guides electric company safety program development and aids compliance with RF safety standards.

Current Year Activities
High-priority research and effective communication form the foundation for the 2012 program. Specific efforts will
• use epidemiologic and laboratory research strategies to investigate the association between residential magnetic fields and childhood leukemia;
• continue a feasibility assessment for an innovative epidemiologic study of EMF and miscarriage;
• investigate the feasibility of laboratory biological models to address potential links between EMF and childhood leukemia, and between EMF and neurodegenerative diseases (Alzheimer’s, amyotrophic lateral sclerosis);
• investigate occupational health and safety issues relevant to power-frequency EMF and RF environments;
• address emerging concerns about potential EMF effects on behavior and health of economically important animals such as honeybees and cattle;
• conduct research relevant to EMF exposure guideline formulation and continue monitoring EMF exposure guideline revisions and related developments;
• provide comprehensive review of potential EMF/RF interference with implanted medical devices;
• investigate cutting-edge RF safety issues, such as RF burns, and create relevant RF safety products, including RF safety tutorials and tools to evaluate the potential for an RF burn hazard;
• develop an educational/training DVD as part of a series that provides comprehensive background on all aspects of the EMF health issue for industry workers; and
• maintain a vital and creative EMF/RF public communications effort for all stakeholders.

Estimated 2012 Program Funding
$5.0M

Program Manager
Gabor Mezei, 650-855-8908, gmezei@epri.com
Summary of Projects

PS60A EMF and RF Health Assessment: Community and Residential Studies (055840)

Project Set Description

Through peer-reviewed scientific publications, presentations at scientific meetings and seminars, and participation in scientific and technical advisory panels, the program staff have an international reputation for rigorous, independent, credible scientific research. EMF/RF issue managers at member companies report that supporting EPRI EMF research is in itself an appropriate response to public concern.

This Project Set includes EMFWorkstation software for modeling both electric and magnetic fields in residential and occupational settings. Also included is the EMF and RF Information Project, which provides clearly presented research results and information to help participants address public concern about EMF and health.

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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P60.001</td>
<td>EMF and RF Information Project</td>
<td>The EMF Information Project provides timely, reliable EMF and RF research information, including communication materials, relevant background information, and “EPRI Comments” on key studies. In conjunction with Resource Strategies’ ELF Gateway and RF Gateway, this project provides e-mailed reports on new research results, scientific meetings, health risk assessments, and regulatory actions.</td>
</tr>
<tr>
<td>P60.002</td>
<td>Laboratory Studies Using Cell and Animal Models</td>
<td>The aim of this research is to study potential effects of magnetic field and, possibly, contact current exposure in an experimental mouse model of childhood environmental leukemogenesis. The project in 2011 provided a description of the model and conducted experiments on positive controls (exposures known to be carcinogenic) to establish a reliable methodology for testing EMF or any suspect exposure. Mouse models are essential in research to identify factors involved in disease development. As an alternative or in addition to an in vivo approach, an in vitro study solicitation is under consideration. This study would consist of a bone marrow preparation exposed to positive controls and then to EMF factors to determine whether biological effects relevant to leukemogenesis occur.</td>
</tr>
<tr>
<td>P60.003</td>
<td>Residential and Community Health Studies</td>
<td>This project includes health studies, analyses of existing data, and evaluations of current knowledge to elucidate the epidemiologic association between magnetic fields and childhood leukemia. Research is in progress to conduct an international case-control study and potentially a cohort study in a highly susceptible population that avoids selection bias and to replicate a much-publicized UK study of childhood leukemia. In addition, an innovative study of EMF and miscarriage is planned, following a pilot phase in 2009. Emerging concerns about potential health and behavioral effects of EMF on animals will also be addressed.</td>
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<tr>
<td>Project Number</td>
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| P60.004        | EMFWorkstation | EMFWorkstation software is a powerful, flexible set of tools for modeling both electric and magnetic fields in residential, commercial, or occupational environments and for evaluating field management options. EMFWorkstation will be maintained for compatibility with current PC operating systems, and any needed enhancements will be addressed. New features will be added only as requested by EPRI members. Work in 2012 will include evaluations of new computing platforms:  
  • Feasibility of developing an iPad tablet computer version in the Apple iOS 4.3  
  • Feasibility of developing an internet-based (cloud computing) version hosted on EPRI servers  
  • Feasibility of developing a new module for electric field shielding by objects outside the ROW (such as trees, buildings, or fences) |
| P60.005        | Residential and Community Exposure Assessment | This new research anticipates growing public concerns about potential exposures associated with smart grid and renewable technologies, electric vehicles, and their charging infrastructure. Exposures, heretofore uncharacterized, will include those from devices such as solar photovoltaics with highly distorted waveforms due to dc/ac conversion, RF exposures from a range of wireless devices, and exposures within electric vehicles. |

**P60.001 EMF and RF Information Project (070650)**

**Key Research Question**

The issue of possible health effects from exposure to the extremely low frequency (ELF) EMF associated with the electric power system and RF associated with a variety of sources (such as panel antennas, wireless networks, and automatic metering infrastructure) continues to generate concern. This is especially true as electric companies undertake new transmission and distribution projects to deliver electricity from new renewable energy resources and as they install smart grid technologies and wireless communication devices to maintain reliable power flow and efficiency. To address public and worker health and safety concerns and effectively manage the EMF issue, electric companies need to stay current on EMF and RF research and have ready access to credible, up-to-date information.

**Approach**

The EMF and RF Information Project provides timely, reliable EMF and RF research information through hard-copy and electronic media. Participants receive communication materials, relevant background information, and “EPRI Comments” on key studies. This project also includes a public EMF web page and a public newsletter that summarizes both EPRI EMF/RF research news and key worldwide news events. In conjunction with Resource Strategies’ ELF Gateway and RF Gateway, this project provides e-mailed reports on newly published research results, health risk assessments, scientific meetings, and regulatory actions. ELF Gateway and RF Gateway websites, with a searchable database of EMF information, are available to participants.

**Impact**

- Improves EMF/RF issue management by providing comprehensive, objective, reliable, and timely information and analyses on possible health effects from exposure to EMF
- Provides issue managers with information to address public and worker concerns about health risks and take appropriate steps to ensure health and safety and to avoid unnecessary costs
How to Apply Results

EMF and RF issue managers will use the materials and information this project provides to stay current on EMF and RF health and safety research, health risk evaluations, and regulatory actions. Managers can also use this information to communicate current knowledge about possible health effects and the results of recent health risk evaluations to concerned workers and the public.

2012 Products

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<th>Product Title &amp; Description</th>
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<tr>
<td>Continuing Updates to EMF and RF Information Project: The EMF and RF Information Project is an ongoing service providing continuous information updates via epri.com, newsletters, and e-mail alerts. The project may also provide hard-copy documents.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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P60.002 Laboratory Studies Using Cell and Animal Models (SP1736)

Key Research Question

In vitro and in vivo laboratory models provide important data for evaluating possible health risks from environmental exposures. In EMF health science, results from laboratory models provide a strong complement to epidemiologic findings. For childhood leukemia, virtually all of the laboratory evidence fails to support epidemiologic evidence of an association with magnetic field exposure. However, no adequate in vivo model of acute lymphoblastic leukemia (ALL), the most common form of childhood leukemia, currently exists. In its 2007 Environmental Health Criteria on EMF, the World Health Organization (WHO) assigned a high research priority to developing a rodent model. Such a model is needed to test the potential effects of environmental exposures, including magnetic fields and contact currents, on childhood leukemia development and progression. Further investigation of neurodegenerative diseases was also identified as high-priority research. As in cancer research, animal models play a crucial role in risk evaluation of neurodegenerative diseases.

Approach

This project has supported the development of an in vivo mouse model of childhood leukemia adaptable to studying potential leukemogenic effects of magnetic fields and other suspected exposures, such as contact currents. Full-scale experiments planned through 2012 will use laboratory models developed in 2009–2011. An additional project aim is to identify the best animal model for use in laboratory investigations assessing a potential effect of EMF exposure in the development of neurodegenerative diseases, such as Alzheimer’s disease.

Impact

- This research provides essential information for health risk assessments by clarifying the plausibility and dose-response characteristics of effects from electric and magnetic fields and contact currents through careful examination of relevant exposures, cell systems, and whole animals.
- By providing accurate experimental evidence for health risk assessments, this research contributes to sound public health policy and helps members address public concern about health risks.
- This research, combined with epidemiologic and exposure assessment studies, will provide accurate scientific information that helps address public concerns about power facility siting, construction, and operation.

How to Apply Results

Publication of research results in the peer-reviewed literature provides accurate information that EMF issue managers can use to address concerns about health risks. Publication of research results also demonstrates the electric power industry’s commitment to resolving uncertainties about EMF and health through active support of the highest quality research. Project involvement will keep members informed on project progress.
and on the most recent scientific development in laboratory science. EPRI is in an ideal position to facilitate broader use and awareness of results by briefing key stakeholders, including policymakers and policy researchers; developing materials for the trade press and the media; presenting at meetings and seminars; and continuing service on various advisory panels.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td>Mouse Model for Pediatric Leukemia: This 2012 interim report will summarize the developed mouse model for childhood leukemia and its potential application to test EMF and contact current.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Animal Models for Neurodegenerative Diseases: This 2014 peer-reviewed literature paper will summarize work started in 2012 on animal models for neurodegenerative diseases.</td>
<td>09/30/14</td>
<td>Peer Literature</td>
</tr>
</tbody>
</table>

P60.003 Residential and Community Health Studies (SP0239)

Key Research Question

On the basis of the epidemiologic association between magnetic fields and childhood leukemia, risk assessments by agencies such as the International Agency for Research on Cancer and the National Institute of Environmental Health Sciences concluded that magnetic fields are a possible human carcinogen. In 2007, the World Health Organization released an assessment that supported this conclusion while noting that uncertainties remain. Uncertainties surround other health endpoints as well, including miscarriage and neurodegenerative diseases such as Alzheimer’s disease and amyotrophic lateral sclerosis. Well-informed EMF health research continues to remain important as other groups, including the BioInitiative Working Group, have called for stringent exposure standards. Along with well-conducted, focused research to resolve scientific uncertainties, effective communication remains essential for EPRI and its members to effectively address developments in EMF health research. With respect to community health impacts, construction of transmission lines in rural areas and transmission lines that link offshore renewable generation facilities (such as wind and wave) to the mainland grid also has raised concerns about potential effects of EMF on animal health and behavior (for example, cattle, deer, bees, and marine life).

Approach

This project addresses, as its main focus, the EMF childhood leukemia issue, with a threefold approach: supporting high-quality, hypothesis-based health studies; analyzing and integrating available data; and synthesizing and evaluating the state of knowledge. The key elements of this project in 2012 are to

- continue the TransExpo study to examine the role of selection bias in the epidemiologic association between magnetic fields and childhood leukemia in a highly exposed population. TransExpo is an international epidemiologic study of children living in multi-level apartment-buildings with built-in transformer rooms;
- replicate the 2005 Draper study, which reported a positive association of distance to power lines with childhood leukemia;
- evaluate the feasibility of establishing a cohort of children with Down syndrome (a group at extremely high risk of developing childhood leukemia) to assess potential EMF effects;
• investigate the relationship between magnetic field exposure and miscarriage; and
• assess the scientific literature to evaluate possible health and behavioral effects of EMF exposure on animals.

Impact
• Improves risk assessment and public understanding by providing timely data and analyses to help resolve key uncertainties related to residential EMF exposure and childhood leukemia
• Clarifies results of previous studies reporting an association between magnetic field exposure and miscarriage
• Addresses public concern about residential proximity to electrical installations
• Fills research gaps in understanding impacts related to environmental EMF exposure generated by renewable energy sources
• Mitigates unintended health consequences of advanced technology integration
• Addresses emerging concerns about potential health and behavioral effects of EMF on animals

How to Apply Results
Results published in the peer-reviewed literature provide accurate information that EMF issue managers can communicate to address concerns about health risks. Publication of research results also demonstrates the electric power industry’s commitment to resolving uncertainties about EMF and health through active support of the highest quality research. Project involvement will keep members informed in advance of formal release of the results in the peer-reviewed literature. In addition, EPRI researchers will facilitate broader use and awareness of results by briefing key stakeholders, including policymakers and policy researchers; developing materials for the trade press and the media; presenting at meetings and seminars; developing software tools; organizing topical workshops and webcasts; and continuing participation on various advisory panels and professional committees.

2012 Products

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<tr>
<td><strong>TransExpo Study Protocol</strong>: This peer-reviewed paper will describe EPRI's TransExpo study, an international study of magnetic field exposure and leukemia in children living in apartment buildings with transformers. In this study, exposure will be determined according to the location of apartments relative to transformer rooms, which reliably predicts exposures. By knowing apartment locations, researchers can assess exposures and minimize the problem of inadvertent exclusion of study participants that can occur when participants are not traceable or refuse to participate.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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<tr>
<td><strong>Evaluation of EMF Impact on Cattle</strong>: A recent series of papers has proposed that transmission lines may affect the behavior of cattle near the lines. This published work used Google Earth images to evaluate cattle grazing patterns and reports a novel finding that cattle statistically align within the geomagnetic field but that the presence of transmission lines disrupts this behavior. This technical report will use an improved geoscience methodology to initially evaluate the first hypothesis that cattle align with the geomagnetic field. If this is not the case, there will be no need to evaluate effects of transmission lines on a nonexistent behavior.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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**Evaluation of High Voltage Direct Current Health Effects Research:** The electric transmission grid is a crucial component of modern society, and one of the most important potential growth sectors within the grid is high-voltage direct-current (HVDC) transmission. Transmission grid operators are working to boost transmission capacity and reliability over the next several years, and it is likely that HVDC will play an important role in grid expansion. HVDC can provide a favorable alternative to overhead alternating current (AC) transmission; it requires a smaller right-of-way and results in lower line losses. The electric environment around HVDC lines has characteristics that differ from those of an HVAC line, such as a static DC magnetic field that can locally affect the geomagnetic field and the presence of corona-generated air ions. There has been public concern about potential health effects related to previous HVDC line projects. This resource paper will summarize the existing health literature on the potential effects of HVDC overhead lines and identify any gaps in knowledge.  

**Childhood Leukemia and Down Syndrome Risk Factors:** Children with Down Syndrome are at a higher risk of leukemia compared with other children. This 2012 review paper will summarize existing literature and will compare and contrast risk factors for childhood leukemia among children with and without Down Syndrome. This summary will help in evaluating whether the leukemias are similar in these two populations. If they are similar, future work will explore a novel concept for epidemiologic research and will identify and follow a cohort of children with Down Syndrome to assess the association between EMF and childhood leukemia.  

**Power Lines and Neurodegenerative Diseases in Denmark:** This project investigates the association between residential exposure to ELF-EMF from power lines and neurodegenerative diseases, particularly Alzheimer’s disease. A 2009 Swiss study was the first to address these associations, and a replication is needed. The design of the study is a register-based case-control study covering the whole of Denmark and aims to improve on the exposure assessment methodology. The 2012 peer-review publication will describe methods used and results from the Danish study.  

**Residence near Power Lines and Childhood Cancer:** This study will replicate the 2005 Draper study, which reported that residing within 600 meters of overhead transmission lines increased leukemia risk among UK children. The replication study will use improved exposure assessment methods and will include calculated magnetic fields and, for houses near power lines, measured fields.  

**Evaluation of EMF Impacts of Underwater Power Cables on Aquatic Life:** Offshore wind turbine projects are being proposed to harness wind energy over the oceans and convert it to electricity. Some of this potential energy may be near major energy load centers where energy costs are high and land-based wind development opportunities are limited. Undersea electric cables are used to connect multiple turbines in the wind facility and transport the electricity to a transformer, where the electricity is converted to a high voltage for transmission via undersea cables to a substation. There the electricity is connected to the onshore electricity grid. There may be concern about potential interference with navigation for endangered and threatened aquatic species. Electromagnetic
fields created by the electric cables running from the turbines and underwater noises and vibrations could affect their orientation and navigational ability. This technical report will summarize the existing literature on the potential effects of EMF due to underwater high-voltage cables on marine life and identify research gaps.

Use of Transmission Line Easements for the Benefit of Native Bees: Final Report: Concern for the maintenance of wild bee populations has increased in recent years, with evidence from Europe and the United States suggesting a general decline in abundance and diversity. The decline in honeybee populations due to colony collapse disorder, pesticides, and parasites has led to efforts to create native bee–friendly habitat as a way to take the pressure off managed honeybee colonies as pollinators. It has been suggested that electric and magnetic fields have adverse effects on bees, including bee behavior and flight performance. This project will determine the impact of electric and magnetic fields on flight performance and behavior of native bees and evaluate the benefits of managed habitat in transmission line easements to local native bee diversity.

P60.004 EMFWorkstation (SP1246)

Key Research Question
The EPRI EMFWorkstation is a versatile software tool for characterizing magnetic fields from power lines and substations in residential, commercial, and occupational environments.

Approach
Over the past decade, the EMFWorkstation has been one of EPRI’s most popular software products. The software provides a cost-effective method for characterizing magnetic field levels and for evaluating different magnetic field management options. In 2012, the software will be updated for compatibility with contemporary PC operating systems, and new features will be included as requested by members.

Impact
- This product provides a versatile tool for characterizing and evaluating magnetic fields in residential, commercial, and occupational environments.
- EPRI’s EMFWorkstation is the only integrated EMF management software available offering accurate results for complex environments in a user-friendly product.

How to Apply Results
Participants (including industrial hygienists and design engineers) can use EMFWorkstation software to model magnetic field environments in residential, commercial, and occupational settings and to evaluate magnetic field management options. Participants can use the output of the models to explain field levels to regulators and other interested parties.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>EMFWorkstation 2012: EMFWorkstation 2012 will have added capabilities as members request them, maintain compatibility with current PC operating systems, and incorporate any fixes required.</td>
<td>12/31/12</td>
<td>Software</td>
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Future Year Products

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<th>Product Title &amp; Description</th>
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</thead>
<tbody>
<tr>
<td>EMFWorkstation 2013: EMFWorkstation 2013 will incorporate fixes, maintain compatibility with current PC operating systems, and add capabilities as members request them.</td>
<td>12/31/13</td>
<td>Software</td>
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</tbody>
</table>

P60.005 Residential and Community Exposure Assessment (070651)

Key Research Question

This project addresses an array of emerging industry research needs, including possible RF exposures from an advanced metering infrastructure (AMI), electric cars, and integration of renewable resources. AMI, which includes automatic meter readers and home area networks, will become increasingly widespread within residences and communities. Questions have already arisen from the public sector about RF exposures associated with these technologies. Other devices introduced into the home, such as wireless chargers, may also prompt questions from the public. Electric vehicles (hybrids and all-electric) are penetrating the public motor vehicle fleet. The operation of such vehicles, to some extent, will generate EMF within the passenger compartment, which is likely to draw questions about health and safety. The associated charging infrastructure in homes and public areas will also result in a new exposure environment. Accurate exposure characterization is essential for addressing such concerns.

Furthermore, unidirectional and bidirectional dc-to-ac converters may be used to incorporate renewable energy sources, such as solar photovoltaics, into existing utility infrastructure. As a result of the dc-to-ac conversion, nonsinusoidal waveforms of higher-order frequency may be created. To reduce uncertainties about exposure to the public as well as workers and to address related public health and safety concerns, scientifically rigorous exposure assessment is required.

To enable the most efficient integration of renewable energy resources, EPRI will conduct comprehensive assessments of power frequency (60 Hz), harmonics, and high-frequency magnetic field exposures in the renewable environment; evaluate exposure for a representative range of system loads and operational conditions; and model the geomagnetic environment.

Approach

This project characterizes ELF and RF electromagnetic fields emitted by AMI devices in residential settings, electric vehicles and related charging infrastructure, and other potential exposure settings related to the new smarter grid infrastructure.

The project will also characterize the electromagnetic environment in proximity to renewable energy infrastructure such as technologies using power electronic dc-to-ac converters. Measurements of power frequency will capture waveform distortions at the source and for a range of representative system loads and operational conditions.

Impact

- This research provides characterization of EMF exposures related to emerging energy technologies, specifically to address residential exposures to RF electromagnetic fields from wireless emitters within residences, in electric vehicles, and from devices that produce distorted waveforms due to dc/ac conversion. Depending upon results, further research may focus on exposure reduction strategies for the public and workers.
How to Apply Results

EMF issue managers can communicate results of EMF characterization results to address growing public concerns about smart grid and renewable technologies and electric vehicles. In addition, EPRI researchers will aid broader use and awareness of results by briefing key stakeholders, including policymakers and policy researchers; developing materials for the trade press and the media; presenting at meetings and seminars; developing software tools; organizing topical workshops and webcasts; and continuing participation on various advisory panels.

2012 Products

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<tr>
<td>Residential EMF Characterization of Renewable Energy Sources: This 2012 technical report will describe the residential EMF environment of selected renewable energy sources.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Assessment of EMF Exposures Related to Electric Vehicles and Charging Infrastructure: This 2012 technical report will describe the EMF environment related to electric vehicles and charging infrastructure. The work presented is an expansion of earlier work done by EPRI.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
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</table>

PS60B EMF and RF Health Assessment: Occupational Studies (055841)

Project Set Description

The Occupational Studies Project Set produces scientific research and information on important occupational health and safety issues related to EMF exposure and RF safety. The Occupational Studies Project Set is also concerned with the technical basis for EMF and RF exposure guidelines. Current guidelines protect against neurostimulatory (EMF) or thermal (RF) effects arising through known biophysical mechanisms; however, guideline limits have not yet incorporated all the recent advances in dosimetry, dose-effect relationships, and exposure modeling, many of these originating from EPRI research. In addition to its contribution to guideline science, EPRI will continue to monitor revisions to guidelines and other developments. EPRI occupational health studies focus on neurodegenerative diseases, particularly amyotrophic lateral sclerosis (ALS) and Alzheimer's disease, among electrical and other workers. EMF and RF occupational health and safety research includes an evaluation of RF assessment of health tool, under practical conditions, the production of an RF safety awareness DVD, and the development of an RF safety reference book.

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<tr>
<th>Project Number</th>
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<tbody>
<tr>
<td>P60.006</td>
<td>EMF and RF Occupational Health and Safety</td>
<td>This project provides a comprehensive assessment of potential links between EMF exposure and health effects among electrical and other workers. In accord with World Health Organization research priorities, work in 2012 will focus on neurodegenerative diseases. This project also includes monitoring of occupational exposure guidelines for EMF and contact current and investigation of related scientific and technical issues. In addition, the project addresses potential interference with implanted medical devices. Research in this project builds on the foundation established through 2011 in RF exposure characterization (source description, measurement techniques, and exposure modeling), dosimetry, and safety program design. Work will begin on organizing and producing the RF Safety Reference Book. Additional work will include an evaluation of personal RF exposure monitor accuracy under practical conditions.</td>
</tr>
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</table>
P60.006 EMF and RF Occupational Health and Safety (070652)

Key Research Question

Epidemiologic studies have investigated health effects possibly associated with work in electrical occupations and with occupational exposure to EMF, contact current, and spark discharge. In its 2007 EMF health risk assessment, the World Health Organization (WHO) assigned a high priority to research on ALS in electrical occupations. WHO also assigned a high priority to research on magnetic field exposure in relation to Alzheimer's disease. Well-conducted research is critical in order to address these issues and develop cost-effective work practices that protect health and safety. In addition, cutting-edge research is essential for formulating appropriate guidelines.

Accurate exposure assessment is critical for minimizing worker exposures near RF and wireless facilities and emerging energy technologies. RF exposure assessment can be facilitated by reliable software for modeling RF fields, dependable RF measurements, and improved dosimetry to estimate the internal body dose corresponding to external fields.

New work environments will be created as electric companies plan new transmission and distribution projects and cope with increasing electricity demand by delivering electricity from renewable energy resources. Possible health effects from exposure to the ELF EMF associated with the electric power system continue to generate concern. The aging workforce and the proliferation of implanted medical devices are converging and driving questions about potential effects from EMF environments. Electric companies need to be able to anticipate the need for quantitative exposure assessment.

Approach

This project provides a comprehensive assessment of potential links between EMF exposure and health effects among electrical and other workers. Key activities in 2012 will include the following:

- A comprehensive review of the literature on EMF/RF interference with implanted medical devices
- A multiyear effort to produce the RF Safety Reference Book.
- An evaluation of the spatial and temporal aspects of electric and magnetic environments associated with occupations in renewable energy infrastructure, including measurements of power frequency (60 Hz), harmonics, and high frequency components in work environments and identification of potential methods to mitigate exposure (such as shielding or design options)
- Development of an RF safety tool for transmission line workers near AM radio transmitters

Impact

- Addresses concerns about worker health and safety by clarifying possible health effects of EMF and RF exposures among electrical and other workers and by assessing occupational exposures. Knowledge about exposures and health effects can aid development of cost-effective, protective work practices, resulting in reduced liabilities.
- Potentially reduces costs associated with guideline compliance by providing scientific input to the formulation of guidelines that are consistent with safety for workers and the general public in EMF environments. Valid input of this nature avoids unnecessarily conservative guidelines, which can result in excessive costs (such as the cost of overly protective gear and of equipment shutdowns) and inconvenient work practices.
- Enables development of more-effective maintenance practices that minimize worker exposures and permit work near RF and wireless installations without costly interruptions and delays.
- Aids commercially viable renewable energy sources by delivering informed, accurate exposure assessments.
How to Apply Results

Electric company occupational health and safety staff will use this work to assess worker exposures to EMF, contact current, and spark discharge and RF and to make informed decisions on any interventions that may be necessary or advisable. Health effects research results will help EMF and RF issue managers address concerns about potential health risks. EPRI researchers will facilitate broader use and awareness of the results by briefing key stakeholders, including policymakers and policy researchers; developing materials for the trade press and the media; presenting at meetings and seminars; and continuing participation on various advisory panels.

Electric company occupational hygienists, managers, and safety specialists will be able to assess worker EMF exposures in renewable technology environments. EPRI research will bridge gaps in worker health knowledge surrounding renewable technologies by communicating with key stakeholders, developing materials for the trade press and media, presenting at meetings and seminars, and continuing participation on advisory panels.

2012 Products

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<tr>
<td><strong>Occupational EMF Characterization of Renewable Energy Sources</strong>: This 2012 technical report will describe the occupational EMF environment of selected renewable energy environments.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>RF Safety Tool For Workers Near AM Radio Transmitters</strong>: This technical report will summarize the map-based methodology used to develop the RF Safety Tool.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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Future Year Products

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<tr>
<td><strong>RF Safety Reference Book</strong>: The RF Safety Reference Book will provide comprehensive information on a wide range of RF safety topics in a practical format. The reference book will include a CD or DVD containing EPRI's RF modeling software and RF measurement training video. Together, the reference book and CD will compile and update all EPRI RF safety work in a convenient source of RF safety information for utility worker populations.</td>
<td>12/31/14</td>
<td>Technical Report</td>
</tr>
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Supplemental Projects

ELF Personal Monitor (070520)

Background, Objectives, and New Learnings
The use of implanted medical devices that address a wide range of health conditions is rapidly expanding (see EPRI Technical Update, "Electromagnetic Interference with Implanted Medical Devices: An Update," Product # 1016815). Although these devices are designed to withstand interference from external electric and magnetic fields, various studies have indicated that the probability that interference can occur cannot be assumed to be zero. A comprehensive workplace safety program would benefit from the availability of a personal monitor that informed a worker with an implanted medical device (such as a cardiac pacemaker or defibrillator) that the electric and/or magnetic field in his or her ambient environment was approaching levels that could conceivably interfere with the implant’s performance.

Project Approach and Summary
The aim of this research is to develop a working prototype of a personal electric and magnetic field exposure meter, with accompanying software and documentation, designed to provide alerts in the presence of high electric or magnetic fields. The monitor will be designed to be easily worn by a person (small, compact, and lightweight) and to be capable of continuously monitoring electric and magnetic field levels within typical electric utility and industrial environments. The monitor could be readily programmed by a company representative for various electric and magnetic field thresholds (for example, by percentages of a known EMF guideline such as that from the American Conference of Governmental Industrial Hygienists) and could alert the wearer in environments where those thresholds are exceeded. The unit will build on the existing features of the EMDEX PAL, which was used successfully and safely in monitoring magnetic field exposures across the United States in the U.S. Research and Public Information Dissemination (RAPID) Program’s "1,000-Person Study." The unit will be adapted to detect electric and magnetic fields up to levels relevant to potential device interference.

The tasks include the following:
- Define meter parameters, specifications, and constraints
- Identify available processors and components
- Develop initial circuit design, breadboarding, and schematic
- Develop internal operating software program
- Finalize breadboard prototype
- Develop initial printed circuit board design and manufacturing run
- Test prototype units at utility sites
- Make final design changes
- Develop PC software
- Prepare user manual and related documentation

Benefits
Cardiac pacemakers and defibrillators are probably the most widely used implanted medical devices, allowing many men and women to return to productive working lives. It is essential that these individuals be provided with an appropriate tool that, when combined with any of a number of other possible measures (such as worker training and appropriate signage), would help minimize the probability of an interference event.
RF Characterization and Health Studies (072035)

Background, Objectives, and New Learnings

The electric utility industry is striving to achieve greater energy efficiency and reliability, and to eventually reduce dependence on fossil fuels by economically and efficiently decarbonizing the electricity sector. The development of a smarter grid, a strategic modernization of the electric power system to integrate new and more-distributed energy resources including renewables, is essential for achieving these goals.

The future electric power system will include new technologies and applications involving electromagnetic environments that remain poorly characterized and whose potential effects on human health and safety are not completely resolved. These environments range from extremely low frequencies associated with plug-in hybrid-electric vehicles and charging apparatuses up to the radio frequencies (RF) associated with automatic metering infrastructure and telecommunications emitters, such as cell phone base stations and paging antennas.

Health and safety concerns may pose barriers to implementation of new technology. Public concerns about the health and safety aspects of electric power transmission and distribution have been evident for several decades, as concerned citizens request assurances of health and safety as new facilities are sited and built. Recently, health concerns related to RF exposures have re-emerged due to the proliferation of mobile phone use and wireless technology. This concern has migrated to RF exposures from utility infrastructure such as smart meters. Several cities in California are calling for suspension of advance metering infrastructure (AMI) programs until the health issues are further clarified.

Given the increasing concerns raised by the public and decision makers regarding RF exposures as smart meters are installed, an accelerated and comprehensive research program at EPRI addressing RF associated with modernized electric power systems is warranted.

Project Approach and Summary

To address health and safety concerns related to technologies of the modernized and expanded smarter grid, research must identify sources of environmental exposure and characterize both ambient and personal exposure levels. Subsequent steps include evaluation of the effective dose in the exposed organisms (including the human body), clarification of biological impacts and physiological interactions (including environmental and internal modifying factors), and, eventually, characterization of human health responses. During this process the research must draw from a variety of scientific disciplines including epidemiology, laboratory toxicology, cellular and molecular biology, medical sciences, engineering, and physics.

In 2011, Technology Innovation– (TI-) funded projects were launched to evaluate the current state of the science in RF health research and to identify new and emerging RF-enabled technologies. The proposed work described will be informed by the 2011 TI-funded work, and the scope of work may be refined accordingly.

Benefits

This work will build on EPRI's wealth of experience in health assessment, exposure assessment, and safety research. The proposed research will contribute to a body of scientific knowledge on the nature of the environment created by the new infrastructure, the exposures' physical interactions with living bodies, and whether those interactions could lead to concern over biological or human health effects. This essential information will inform decision makers, regulatory agencies, and the public, facilitating timely deployment of technologies used to enhance electrical system efficiency and reliability.
Water Quality and Watershed Protection - Program 53

Program Overview

Program Description
The U.S. Environmental Protection Agency (EPA) is committed to watershed-based resource management and protection strategies that integrate Total Maximum Daily Loads (TMDLs) with National Pollutant Discharge Elimination System (NPDES) permits, allowing for innovative compliance approaches such as water quality trading. Even as TMDL implementation continues, existing permit limits become more stringent and additional contaminants face regulation, while new air quality control systems are changing the characteristics of utility discharges. Water quality, water resource, and environmental compliance managers are challenged to address these issues from watershed and end-of-pipe perspectives. Site-specific TMDL, permitting, and implementation guidance is needed to manage multimedia releases while minimizing the associated economic costs and environmental and health impacts.

The Electric Power Research Institute’s (EPRI’s) water quality and watershed protection program advances scientific knowledge and technology development to mitigate the risks associated with power plant discharges of mercury, arsenic, selenium, nitrogen, and other compounds into aquatic environments. The program helps industry, regulators, and other stakeholders develop and implement cost-efficient, risk-based strategies for watershed protection and permitting. It delivers advanced analytical and modeling techniques to allow site-specific conditions and new ecological understanding to be incorporated in regulatory and permitting processes. It also expands the knowledge base and available options for addressing mercury and nitrogen emissions, drinking water standards, TMDLs, and watershed management.

Research Value
EPRI brings a comprehensive approach to water quality management and watershed protection, accounting for multimedia emissions from power plants, the impact of new environmental control systems on aquatic discharges, and the contributions of other point and nonpoint sources. The program provides scientific, risk-based information and tools for use by members, regulators, and other stakeholders in developing permit limits, regulations, standards, TMDLs, and management plans addressing human health, aquatic toxicity, eutrophication, and other issues. By helping reduce reliance on assumptions that may under- or overestimate risks, the program supports economically and ecologically sound decision making. Research results allow for opportunities to

- develop site-specific water quality criteria and inform watershed-driven policy and regulations;
- implement TMDLs that incorporate atmospheric deposition in a technically sound manner;
- develop novel watershed-based management approaches such as water quality trading;
- participate in and benefit from leading-edge collaborative research by industry, state and federal agencies, and other research organizations; and
- plan and implement research on emerging concerns and pressing issues, such as effects of increased total dissolved solids and ammoniated discharges on water quality parameters.

Approach
EPRI research addresses current priorities and emerging issues, including risk-based management of mercury, arsenic, selenium, nitrogen, and other contaminants on a site-specific and watershedwide basis; implementation of best management practices and advanced analytical methods; and effects of environmental control equipment such as scrubbers on power plant discharges and receiving waters. The program is also forward-looking, examining concerns not yet widely recognized, such as how changing aquatic discharge characteristics may impact threatened or endangered species. This program delivers

- research on selenium to determine the level of risk for noncompliance with the tissue-based criterion and to develop site-specific criteria protocols for compliance;
• research on mercury to enhance the Dynamic Mercury Cycling Model (D-MCM) for compliance purposes and to develop site-specific criteria protocols for compliance;
• presentations to state and federal decision makers and other stakeholders considering mercury and other air toxic emissions regulations;
• peer-reviewed literature and other information on arsenic bioaccumulation;
• arsenic health risk estimates to inform development of a scientifically defensible human cancer potency factor;
• information for watershed and TMDL regulatory compliance and management decisions with respect to mercury, nitrogen, metals, heat, sediments, and acidity;
• water quality trading and ecosystem services approaches for reducing compliance costs;
• assessment of ammoniated wastewater effects; and
• collaborative work with other EPRI programs in areas such as atmospheric deposition, effluent characteristics, and the effects of climate variability on water availability and quality.

Accomplishments
Engaging domain experts, collaborating with and providing technical assistance to EPA and other agencies, and developing a substantial volume of peer-reviewed literature are critical in informing the development of cost-effective and protective regulations and permit conditions. Applications of program results have produced documented site-specific compliance cost savings ranging from tens of thousands of dollars up to more than $10 million. Program accomplishments include the following:

• Early results from EPRI’s arsenic research provided support for revision of a state’s ambient water quality criteria for arsenic, providing regulatory relief for two utilities while still protecting human health and the environment.
• EPA’s Health & Ecological Criteria Division is working with EPRI on arsenic ambient water quality criteria.
• Mercury research has played a critical role in increasing understanding of the fate of mercury in the environment and helped place power plant emissions in a global context, informing policy and regulatory dialogues.
• The D-MCM continues to be applied by EPA and states to examine and predict mercury bioaccumulation in aquatic environments and to inform TMDL development.
• The Electronic Watershed Assessment and Management Tool and the Watershed Analysis Risk Management Framework were applied in demonstration projects and by state and federal agencies for watershed management and TMDL calculation, verification, allocation, and implementation.
• EPRI tools have supported scientific and technical evaluation of regional TMDLs and cross-pollutant trading practices, laying the foundation for the world’s largest water quality trading program.

Current Year Activities
Program R&D for 2012 focuses on D-MCM case studies to improve prediction of the environmental fate and transport of mercury, using data from the Ohio River; updates and expansion of web-based references for TMDL implementation and watershed management; evaluation of approaches to multimedia TMDLs; and water quality trading. Specific efforts will include

• conducting D-MCM case studies, starting with data from the Ohio River, to support compliance needs related to the new EPA methylmercury fish tissue criterion;
• conducting collaborative research with the University of Illinois and the U.S. Geological Survey on a new method for analyzing methylmercury in water;
• refining an EPRI-developed approach for generating site-specific selenium water quality criteria;
• improving the scientific basis for estimating arsenic health risks;
• determining potential risks to freshwater mussels and other aquatic organisms from ammonia and total dissolved solids in discharged waste water; and
• collecting information to support the continued development of water quality trading pilot projects.
## Estimated 2012 Program Funding

$1.4M

## Program Manager

John W Goodrich-Mahoney, 202-293-7516, jmahoney@epri.com

## Summary of Projects

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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tr>
<td>P53.001</td>
<td>Arsenic Health Risk Estimates</td>
<td>A joint EPRI/EPA cancer risk assessment framework is expected to reduce critical uncertainties regarding arsenic’s mode of action and toxicokinetics at low exposure levels. This research will apply new biological information to reduce uncertainties in the cancer health risk assessment for arsenic and will reduce reliance on conservative default assumptions in human health risk estimates.</td>
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<tr>
<td>P53.002</td>
<td>Ammoniated Wastewater Assessment</td>
<td>Many power plants are or will be installing SCR equipment and scrubbers as air quality regulations evolve. There is uncertainty as to how these control technologies might affect wastewater quality and toxicity. The information developed in this project can be used to better inform utilities on the management of ammonia and other constituents in waste streams, especially if such waste streams are to be comanaged in fly ash basins.</td>
</tr>
<tr>
<td>P53.003</td>
<td>Aquatic Life Criteria Development</td>
<td>This research builds on a critical assessment of the process by which EPA establishes national ambient aquatic life criteria. That assessment, undertaken with EPA, to develop improved, scientifically based methods included an evaluation of the 1985 EPA report, Guidelines for Deriving National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses.</td>
</tr>
<tr>
<td>P53.004</td>
<td>Dynamic Mercury Cycling Model (D-MCM)</td>
<td>The D-MCM will assist dischargers in addressing complex issues associated with mercury regulatory requirements. Research conducted will enhance the applicability of the D-MCM to diverse aquatic ecosystems, ultimately providing a tool to predict ecosystem responses as a function of atmospheric mercury deposition rates.</td>
</tr>
<tr>
<td>P53.005</td>
<td>TMDL/Watershed Issues</td>
<td>This project addresses complex scientific, technical, and economic issues concerning TMDLs, watershed management, atmospheric deposition effects, mercury and nitrogen discharges, and stormwater runoff.</td>
</tr>
<tr>
<td>P53.006</td>
<td>Water Quality Trading</td>
<td>This project will evaluate water quality trading as a cost-effective and ecologically defensible option for compliance with increasingly stringent water quality standards.</td>
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P53.001 Arsenic Health Risk Estimates (SP0489)

Key Research Question
The planned revision of the arsenic ambient water quality criterion may result in more-stringent limits if the current no-threshold linear default extrapolation for cancer risk is applied. This research will reduce reliance on default assumptions and uncertainties in the scientific basis for human health risk assessment for arsenic, leading to sounder regulatory decisions for wastewater discharges.

Approach
Although recent scientific evidence suggests a nonlinear mode of action for arsenic, a comprehensive risk framework for these observations has yet to be developed. The principal objective of this project is to develop such a framework. Laboratory research to describe kinetics and develop models for arsenic’s behavior in the human body will be conducted. Laboratory studies also will measure the effect of different arsenic exposure levels on important molecules and genes in animal and human cells. Field studies will measure and compare laboratory results with similar endpoints in exposed humans. Results will be integrated into a new, comprehensive, scientifically based cancer risk framework for arsenic that may then be applied to regulatory revisions for wastewater discharges.

Impact
- EPRI works closely with EPA to develop a human cancer risk framework for arsenic that can accommodate nonlinearity in exposure response.
- Use of new data to develop this framework enhances reliance on science and reduces uncertainties in human health risk assessment for arsenic by reducing reliance on conservative default assumptions in human health risk estimates.
- Program research leads to more scientifically sound regulatory decisions for wastewater discharges.

How to Apply Results
As credible, rigorous scientific results are released in the public domain, members should be proactive in sending key stakeholders the results, making sure that stakeholders understand those results, and suggesting that results be considered as environmental policies are developed. Members should also use this information to communicate with various public groups as necessary. In addition, EPRI staff will facilitate broader use and awareness of the results by briefing key stakeholders, including EPA and other government agencies; developing materials for the trade press/media; and continuing service on various advisory panels.

2012 Products

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<tr>
<td>Application of Computational Systems Biology to Describe Arsenic Toxicity Pathways: Genomic and kinetic information for cellular response pathways will be integrated in a computational framework to identify key biological events in the cancer induction pathway that could give rise to low dose–dependent transitions and thresholds. This information is key to understanding the nonlinear human response to arsenic exposure in the low-dose range (the range in which humans are exposed) in order to be able to establish the threshold response for developing the cancer slope factor.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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Future Year Products

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<tr>
<td>Integration of Genomic Ontology Pathway Analysis to Refine Cancer Health Risk Associated with Low Exposure to Arsenic: Gene expression changes in critical tissues associated with arsenic dose and exposure duration will be mathematically integrated to identify those doses at which individual cellular processes are altered.</td>
<td>12/31/13</td>
<td>Peer Literature</td>
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P53.002 Ammoniated Wastewater Assessment (057716)

Key Research Question

Electric utilities are continuing to install selective catalytic reduction (SCR) and selective noncatalytic reduction (SNCR) units to reduce nitrogen oxides for control of ground-level ozone. In some cases, utilities are injecting ammonia to mitigate for sulfur trioxide emissions. Each of these technologies releases ammonia, which may be conveyed to fly ash ponds and landfills. Additionally, many utilities are retrofitting controls for sulfur dioxide on existing units, which will produce solid and liquid discharges, some of which will be placed in landfills.

Approach

Anticipated increases in ammonia and metals in waste streams may lead to currently unknown synergies and the potential for elevated toxicity of discharges. This project's research will include

- field studies to predict future changes in composition of waste streams and fly ash pond waters,
- laboratory studies to evaluate and predict synergistic toxicity of complex mixtures, and
- laboratory and field studies to estimate the potential of discharges for toxicity to current and future threatened species (such as freshwater mussels).

Impact

- Improves the understanding of how air emission control technologies affect wastewater quality, thereby reducing risks and costs associated with discharge compliance requirements
- Identifies potential discharge effects on aquatic life at an early stage so mitigation can be considered
- Avoids future treatment costs by identifying potential synergisms of ammonium and other constituents before they are actually mixed in discharge waste streams (that is, identifies necessary segregation and/or treatment of discharge waste streams)

How to Apply Results

EPRI reports on the potential toxicity of ammoniated ash pond wastewaters will provide guidance for ash pond managers and staff responsible for regulatory compliance in determining whether there is a need to manage and treat separate waste streams prior to discharge. Laboratory studies to be conducted during 2009–2011 will provide benchmark data on whole effluent toxicity before new discharge waste streams (primarily wet-scrubber wastewater) become commingled with ash pond waters. These results will be crucial for planning future research that will be necessary for a priori evaluations of changes in ash pond discharges.

2012 Products

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<th>Product Title &amp; Description</th>
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<tr>
<td>Guidance Manual for Implementing the U.S. Environmental Protection Agency's Ammonia Criteria: This guidance manual will assist utilities in implementing ammonia criteria, which are based mainly on the presence or absence of freshwater mussels.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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### Future Year Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Site-Specific Criteria and Toxicity Testing: An updated guidance manual will be prepared for developing site-specific criteria and whole effluent toxicity limits for flue gas desulfurization– and ammonia-influenced aqueous discharges.</td>
<td>12/31/13</td>
<td>Technical Report</td>
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**P53.003 Aquatic Life Criteria Development (101916)**

### Key Research Question

EPA develops national ambient water quality criteria, which are then implemented by the states. Utilities are subject to limits on metals and other substances in their discharge permits based on existing criteria and also on new criteria as those are developed and implemented. There is a need for improved, scientifically based methods for the development of water quality criteria to ensure that the criteria reflect the latest science, and, over the long term, a need for development of modeling approaches that describe more accurately the risk to aquatic life from the release of metals to surface waters. The Biotic Ligand Model (BLM) is such an approach. Use of the BLM will result in metal-related national ambient water quality criteria being implemented on site-specific bases, with the potential for less-conservative discharge permit limits that are still protective of aquatic life.

### Approach

This project supports critical assessments of the process by which EPA establishes national ambient aquatic life criteria. Several ambient water quality criteria will be revised by EPA, and this research will provide new information to offer a strong scientific foundation for these revisions. The research will also provide guidance on emerging constituents of interest to EPA and state regulatory agencies.

### Impact

- Reduction in compliance costs through rigorous, scientifically valid models for deriving site-specific water quality criteria
- Potential for compliance-cost reductions over the long term through addition of other metals to the BLM
- Assurance that up-to-date scientific knowledge (for example, metals speciation) is considered in criteria development
- Excellent working relationship with EPA, which increases the likelihood that EPA will use research results

### How to Apply Results

EPRI disseminates results to members, EPA, and the public through technical reports, peer-reviewed literature, workshops, and meetings. This project is an effort to improve the development of ambient aquatic life criteria at the national level over the long term, streamlining the process and reducing the costs of compliance. Members will also find project results useful in discussions with state water agencies.

### 2012 Products

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<th>Product Title &amp; Description</th>
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<th>Product Type</th>
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<tbody>
<tr>
<td>Nanomaterials--Environmental Effects: A paper will discuss the emerging use of nanomaterials within power plants and the potential human health and environmental effects when these materials are released to the environment.</td>
<td>06/29/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
**Guidance Manual for Developing Site-Specific Selenium Criteria:** This guidance manual will assist utilities in developing site-specific selenium criteria as a result of EPA’s publication of the selenium fish tissue–based criterion.

**Aquatic Toxicity of Total Dissolved Solids:** EPA may consider further regulation of total dissolved solids to protect aquatic species. Effluent toxicity bioassays will be conducted to characterize the potential toxicity of coal-fired power plant effluent and to inform operators so that they may alter processes, if necessary.

### Future Year Products

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<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Total Dissolved Methylmercury Concentration in Two Headwaters Streams:</strong> This report will present a comparison between measurements of dissolved methylmercury concentrations in water samples collected from two headwaters streams, obtained using the current standard method (FMeHgDE) and a new thiourea-catalyzed SPE method (FMeHgTU) developed at the University of Illinois. This research is being conducted in collaboration with the U.S. Geological Survey’s National Water Quality Assessment Program.</td>
<td>04/30/13</td>
<td>Technical Report</td>
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<tr>
<td><strong>Compilation of Bioaccumulation Models:</strong> This deliverable will comprise a compilation of bioaccumulation models, with information on the strengths and weaknesses of each model, settings in which each is appropriate, costs, and other characteristics.</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Development of an Episodic Biotic Ligand Model:</strong> Current effluent guidelines and water quality criteria are based on toxicity data generated during constant exposure to aquatic organisms. However, research has demonstrated that concentrations in effluents vary daily and even hourly. Further, stormwater regulations will rely on these conservative toxicity assessments, resulting in very low levels of allowable contaminant release. Developing a predictive model to use for setting effluent and stormwater contaminant limits would result in more-realistic and more-attainable permit limits.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Wildlife Mercury Criteria:</strong> EPA has developed a tissue-base criterion for mercury to protect human health from the consumption of fish. This paper will explore where this criterion may or may not be protective of wildlife that consume fish (for example, birds), and if not, what actions might be expected from federal and state governments.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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**P53.004 Dynamic Mercury Cycling Model (D-MCM) (103348)**

**Key Research Question**

Anticipated hazardous air pollutant controls will reduce mercury emissions and deposition. The degree to which controls will affect the environment and improve public health is still uncertain. To cost-effectively maximize the benefits of these controls, it is critical to have a detailed understanding of mercury cycling and be able to simulate its cycling with state-of-the-art models.
Approach
The Dynamic Mercury Cycling Model (D-MCM) will assist dischargers in addressing complex issues associated with mercury in the aquatic environment and concentrations in fish tissue. Project research will include

- environmental mercury research to determine the effect of mercury controls on mercury methylation, bioavailability, and food web transport;
- collaboration with EPA and the U.S Geological Survey to develop long-term monitoring plans for mercury in U.S. watersheds;
- updating of the D-MCM to permit the translation of the methylmercury fish tissue chronic criterion to a water permit; and
- linking of the D-MCM to EPRI's Watershed Analysis Risk Management Framework (WARMF), a whole-watershed transport model.

Impact
- Site-specific application of the D-MCM may help reduce compliance costs at individual facilities through an improved understanding of mercury dynamics in the new environment.
- Biogeochemical processes that convert inorganic mercury to its toxic form can be better managed.

How to Apply Results
Although discharges of mercury and methylmercury in aqueous streams from power plants are currently regulated at some power plants under NPDES permits, in the future, more power plants will likely be regulated as a result of EPA's publication of a water quality criterion of 0.3 mg/kg of methylmercury in fish. The D-MCM will serve to predict fish responses to changes in discharge limits. The model can be used by utility personnel responsible for regulatory compliance to evaluate scenarios and develop discharge limits that are sufficiently protective of human health. The model also can be used by regulators, stakeholders, and academicians. The software will operate on modern PCs, and product support will be provided to program members.

2012 Products

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<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Dynamic Mercury Cycling Model V4.0 (D-MCM):</strong> As a test case, the newly updated D-MCM will be used to predict fish tissue methylmercury concentrations using a robust data set from the Ohio River (mercury fish tissue and water quality data from utilities and the Ohio River Valley Water Sanitation Commission). The model-predicted fish tissue methylmercury concentrations will be compared with measured fish methylmercury concentration data to test the predictive ability of the D-MCM. Based on the results of the Ohio River case study, additional case studies may be undertaken for further validation of the D-MCM.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Controls on Fluxes of Mercury into Aquatic Food Webs:</strong> Continued reporting on laboratory and field research will be conducted under the Mercury Experiment to Assess Atmospheric Loading in Canada and the United States (METAALICUS) project delineating ecosystem-level responses to mercury loading. Results will be used to update the D-MCM.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
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Future Year Products

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<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Dynamic Mercury Cycling Model V 4.0 (D-MCM):</strong> EPRI will hold a workshop for members, EPA, and state staff to explain and demonstrate the D-MCM V5.0 for addressing mercury permit limits and TMDLs.</td>
<td>10/23/13</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Controls on Fluxes of Mercury into Aquatic Food Webs:</strong> This product will be the final report on laboratory and field research conducted under the METAALICUS project delineating ecosystem-level responses to mercury loading.</td>
<td>12/31/13</td>
<td>Peer Literature</td>
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**P53.005 TMDL/Watershed Issues (101920)**

**Key Research Question**

A principal strategic objective of EPA is to use a watershed approach through the implementation of Total Maximum Daily Loads (TMDLs) and watershed-integrated NPDES permits to achieve protection of water resources. This action creates a growing number of new, complex research needs. Research is needed to understand how to effectively manage stormwater runoff; couple watershed and air quality models to address TMDLs where atmospheric deposition is a major source of pollutants such as nitrogen and mercury; derive, allocate, and implement complex TMDLs (involving, for example, thermal, selenium, and arsenic); and increase value to members of EPRI’s web-based watershed management reference.

**Approach**

This project will create decision-support frameworks, water resource knowledge bases, and advanced technology evaluations. These tools will allow development of innovative watershed management plans, derivation of TMDLs, analysis of alternative TMDL loading allocations and implementation plans, evaluation of watershed-integrated NPDES permits, and assessment/management of atmospheric deposition effects.

**Impact**

- Technically sound and economically efficient watershed, TMDL, and NPDES regulatory compliance and management decisions
- Potential facility-specific savings ranging from tens of thousands to tens of millions of dollars
- Potential reduction of costs, estimated to be approximately $17 billion industrywide, associated with the current TMDL rule

**How to Apply Results**

Power company environment staff will consult the EPRI web-based reference tool and EPRI technical reports to help derive more environmentally effective and cost-efficient TMDLs and watershed management plans through application of innovative technologies and strategies, including water quality trading. Information and data will be used by power company environment and generation staff, power company strategic planners, key watershed stakeholders, regulatory agencies, and the public. In addition, EPRI staff will facilitate broader use and awareness of the results by conducting webcasts; briefing key stakeholders, including EPA and state agencies; developing materials for the trade press/media; and continuing service on various government, academic, industry, and professional organization advisory panels.
2012 Products

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<tr>
<td><strong>Multimedia Watershed Interactions - Year One:</strong> This work is the first year of a two-year study to review and evaluate potential consequences of proposals and actions by government agencies and other organizations to use multimedia approaches to assessing and managing atmospheric emission impacts on near- and far-field watersheds. Specific attention will focus on coal plant permitting, Clean Water Act 319(g) petitions, and endangered species. Work will be conducted in close collaboration with EPRI’s Air Quality Area. Based on the ongoing review and evaluation, the second year of this study will focus on defining research and modeling research needs.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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Future Year Products

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<tr>
<td><strong>Multimedia Watershed Interactions - Year Two:</strong> This work is the second year of a two-year study to review and evaluate potential consequences of proposals and actions by government agencies and other organizations to use multimedia approaches to assessing and managing atmospheric emission impacts on near-and far-field watersheds. Specific attention will focus on coal plant permitting, Clean Water Act 319(g) petitions, and endangered species. Work will be conducted in close collaboration with EPRI’s Air Quality Area. Based on the ongoing review and evaluation, the second year of this study will focus on defining research and modeling research needs.</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Multimedia Watershed Case Study - Year One:</strong> This research is the first year of a three-year study. In collaboration with program members, two contrasting watershed case studies will be chosen and started to illustrate the derivation and analysis of a complex multimedia TMDL or a watershed-integrated NPDES permitting analysis.</td>
<td>12/31/14</td>
<td>Technical Resource</td>
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P53.006 Water Quality Trading (070654)

**Key Research Question**

Water quality trading is one of several EPA-approved market-based approaches for addressing complex environmental issues. This project will work to establish water quality trading as a business-appropriate, cost-effective, and ecologically defensible option for the power industry to comply with increasingly stringent permit limits and in-stream water quality standards. Building on EPRI’s Ohio River Basin Trading Program, likely to become the largest water quality trading program in the world, EPRI will identify lessons learned, hurdles, and optimizations that can be applied to any program in the country.

**Approach**

As the use of water quality trading is receiving increasing attention throughout the country, this effort will determine the extent that water quality trading will be an agency-approved compliance tool for meeting future steam electric effluent limits for nutrients, regional TMDLs, state-based nutrient standards, and emerging rigorous national water quality criteria. This will be assessed from both a legal and regulatory perspective and the results will be applicable across the United States.
Impact

- Facility-specific savings of $700,000 or more
- Shaping of national approaches for water quality trading programs and other market mechanisms
- Establishment of water quality trading as a viable compliance alternative for the power industry
- An interim compliance approach during power plant operational transitions

How to Apply Results

EPRI members will understand and their costs and benefits of using water quality trading to cost-effectively meet permit limits.

2012 Products

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<tr>
<td>Case Studies of Water Quality Trading being used for Compliance with NPDES permits Limits: This project will research and summarize real case studies across the United States of NPDES permit holders that have used water quality trading to meet their nutrient compliance requirements.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Impact of Key Industry Issues on Opportunities in WQT (Effluent Guidelines, Zero Liquid Discharge, Dry Ash Ponds, etc).: This report will research and summarize the various regulations facing the industry that may affect the ability to use water quality trading, and assess the likelihood that these regulations will obviate the need for trading.</td>
<td>06/15/12</td>
<td>Technical Report</td>
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Future Year Products

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<tr>
<td>Barriers and Solutions for Stacking Water Quality Credits and Greenhouse Gas Offset Credits: This article will summarize the key aspects of stacking water quality credits for nitrogen and greenhouse gas offset credits for avoided nitrous oxide emissions on farms. The article will describe the critical aspects of credit stacking that will ensure the ecological validity of the practice.</td>
<td>06/15/13</td>
<td>Peer Literature</td>
</tr>
<tr>
<td>Supporting Ecosystem Services and Sustainability Targets via Water Quality Trading: This report will research and summarize how participation in water quality trading can help a company achieve NPDES permit obligations as well as support ecosystem services and sustainability targets.</td>
<td>12/31/13</td>
<td>Technical Report</td>
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Supplemental Projects

Water Quality Trading: Pilot Trades for Compliance with Nutrient Criteria and Greenhouse Gas Targets (071650)

Background, Objectives, and New Learnings

Water quality trading (WQT) is an innovative market-based approach to achieving water quality standards through credit programs, allowing emitters to purchase nutrient reductions from another source. It allows cost-effective compliance with in-stream nutrient targets by funding a combination of agricultural best management practices and environmental restoration projects that will achieve the same or better nutrient reductions compared with installation of high-cost technological solutions. Funding conservation practices through WQT has the potential for accelerating greater, long-term societal and environmental benefits such as sequestering greenhouse gases (GHGs), protecting biodiversity, restoring wetlands, and establishing recreation areas for hiking and fishing. WQT may allow companies to achieve cost-effective regulatory compliance, and also position companies to meet ecological targets for the benefit of society and the industrial community alike.

Based on a platform established under the EPRI-led Ohio River Basin water quality trading project, EPRI intends to pursue the execution of water quality pilot trades. Launched in October 2009, the Ohio River project is a first-of-its-kind regional multicredit trading program and represents a comprehensive approach to designing and developing markets for nitrogen, phosphorus, and GHG credits. The scale of the project is large enough to generate significant regional water quality improvements and serves as the test-bed for pilot trades. More details can be found at www.epri.com/ohiorivertrading.

Project Approach and Summary

With broad interstate interest and support, this effort will focus on executing pilot trades. It will mark an important milestone in assessing the value of power company participation as a buyer of credits in WQT markets. The project’s goals are to:

- Potentially execute one or more pilot trades involving an EPRI member company(s): Water quality credit trades for nitrogen may be executed in the project area, with a preference for opportunities to acquire GHG credits. If credits are generated, EPRI will act as the aggregator of credits, which may be sold, donated, or retired, as appropriate. EPRI member company(s) will be notified of opportunities to purchase credits.

- Finalizing Pilot Trading Framework: Critical design considerations for a properly constructed program will involve key elements that will determine the rules and framework for a regional trading program, such as credit trading ratios, credit calculation methods, verification and monitoring of nutrient reductions, and the role of the watershed model in governing trades. This effort will develop a trading framework for power companies.

- Modeling: The Watershed Analysis Risk Management Framework (WARMF) model will inform trading program design by simulating the in-stream outcome of water quality credit trades, evaluating the potential watershed impact of different trading approaches, and tracking progress toward achieving nutrient reduction goals. This effort will build on EPRI’s work to establish a WARMF watershed model of the Ohio River Basin (EPRI Report 1018691) and will provide an ecological context for the trading program.

- Facilitate Stakeholder Support: Pilot trades will require approval of EPA permitting authorities, support from the U.S. Department of Agriculture (USDA), and possibly interstate agreements. EPRI will endeavor to facilitate these agreements and acquire necessary support to execute pilot trades.

- Evaluate Credit Stacking: EPRI is currently preparing several benchmark publications to inform credit stacking—that is, getting more than one credit type for a given conservation action. This project will use WQT pilot trades to assess opportunities for stacking both GHG and nutrient credits. The project will work with the participating farmers to estimate GHG credits generated through adopted agricultural practices and assess
different calculator tools and protocols, including the newly released USDA COMET VR 2.0 tool. This effort builds on EPRI research to quantify GHG credits for avoided fertilizer use on farms (EPRI Reports 1015463 and 1018364). GHG credits resulting from this effort may be offered for sale, if appropriate.

Benefits

Water quality trading has potential as an integral part of corporate water nutrient compliance strategies for facility upgrades, retirement, or mitigation of difficult seasonal discharge management periods. Some companies may benefit as either a purchaser or a provider of credits. Others including the public will benefit by helping to resolve key technical issues that may determine the future of trading as a compliance tool for multiple public and industrial entities, as well as evaluating ancillary environmental and economic benefits associated with WQT.

This project intends to provide the technical basis for resolving key issues to determine the efficacy of water quality trading. These issues include quantifying credits, demonstrating the viability of watershed modeling as a basis for trades, establishing technically sound yet reasonable verification and monitoring requirements for credit generation, demonstrating the viability of interstate trades, testing the likelihood of stacking GHG and water quality credits, and other issues. The pilot trades will also demonstrate the business case for credit sellers and buyers, necessary for securing long-term stakeholder interest.
Fish Protection at Steam Electric Power Plants - Program 54

Program Overview

Program Description
A primary challenge for power plant owners is to ensure adequate water supplies for operations while protecting aquatic life living in the lakes, streams, rivers, estuaries, and oceans those operations impact. In the United States, the Clean Water Act §316(b) requires plant owners to install fish protection technologies on cooling water intake structures, while §316(a) requires management of thermal discharges. The information and learnings of this program may have direct benefits to international programs and as such, can be implemented through additional efforts.

The Electric Power Research Institute's (EPRI’s) fish protection program assesses the effects of thermal power plant cooling system operation on fish and other aquatic life. Results support the development of effective intake and discharge protection approaches for workable operating permits at individual facilities. By improving the technical basis for regulatory, permitting, and operating decisions, this program serves the public interest in effective resource management while meeting industrywide imperatives to control costs, ensure or even exceed environmental compliance, and manage business risks.

Research Value
Technical information and research results inform the U.S. Environmental Protection Agency's (EPA’s) §316(a) and (b) policy and regulatory analyses and can inform similar regulations in other countries. Program results defray or avoid research costs that could range from hundreds of thousands to millions of dollars if funded independently. Program information may reduce compliance costs, enhance permitting processes, and identify cost-effective management strategies. The program also provides access to new and enhanced fish protection technologies, information on fish protection–related issues, and information on costs, economic, environmental, and electric system impacts of a potential national requirement for a retrofit of closed-cycle cooling systems. The key motivations for this research are

- evaluating challenging impingement mortality reduction standards for those plants withdrawing more than 125 million gallons of water per day (MGD) to meet entrainment protection standards developed on a site-specific basis;
- evaluating the latest information on technologies for reducing impingement and conducting benefit analyses to support development of site-specific entrainment standards;
- examining closed-cycle cooling retrofit options, which, for once-through–cooled facilities, could cost between $50 million and $1 billion, have a suite of their own negative environmental impacts, and have short-term impacts on grid reliability;
- avoiding duplicative costs of doing multiple pilot demonstrations of technologies; and
- assessing the economic benefits associated with reducing impingement and entrainment; EPRI research is critical to support this assessment process.

Approach
This program provides information, analytical tools, innovative mitigation technologies, and expert services to help environmental compliance managers and power plant operators effectively manage water resources and protect aquatic communities in accordance with fish protection regulations. The program also provides methods to support technology performance verification monitoring. The program delivers

- collaboration with industry, professional scientific societies, and federal agencies;
- translation of complex scientific and engineering information into easy-to-understand, site-specific problem solving;
- credibility with resource agencies when addressing specific permit issues;
• biological sampling and fish health assessment information and protocols;
• analysis and performance evaluation of fish protection technologies (traveling screen systems, vacuum pump systems, wedge-wire screens, and barrier net systems), including technology design, construction, operation and maintenance requirements, and costs; and
• thermal discharge risk analyses.

Accomplishments
Program information supports current industry compliance efforts as well as updates to guidance on thermal discharge assessment variance procedures. The information is expected to support a regulatory structure that is informed by scientific and engineering information. Program accomplishments include

• information on performance of intake fish protection technologies in identifying best technology available (BTA) for new and existing power plants, as required under §316(b);
• impingement mortality and entrainment sampling information in support of §316(b) compliance;
• technical resource documents on fish protection technology performance and costs;
• technical information on the impacts and the environmental and economic benefits of reducing impingement mortality and entrainment; and
• technical workshops and symposia for technical information and technology transfer.

Current Year Activities
Program R&D for 2012 will focus on developing information on approaches for attaining intake system design through-screen velocities below 0.5 feet per second (fps), evaluating the cost trade-offs of reconfiguring to 0.5 fps design intake velocity versus installing traveling water screens or other impingement reduction technologies, evaluating entrainment protection technologies, preparing verification monitoring procedures, and developing information and tools to support industry’s efforts to comply with the revised §316(b) existing facility regulation. Specific research efforts will include

• evaluating the performance of intake fish protection technologies for reducing impingement mortality and entrainment;
• developing guidance on approaches and costs for reducing design through-screen velocities to below 0.5 feet per second;
• developing verification monitoring procedures for evaluating fish protection technology performance;
• assessing the engineering, economic, and environmental consequences of potential closed-cycle cooling systems retrofits on power plants with once-through cooling systems;
• developing fish thermal tolerance data to support technically defensible thermal discharge permit criteria;
• investigating the causes of discrepancies between laboratory and field observations of fish response to thermal plumes; and
• transferring information and application services via workshops, conferences, and consultations with members.

Estimated 2012 Program Funding
$3.6M

Program Manager
Douglas Dixon, 804-642-1025, ddixon@epri.com
Summary of Projects

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<tr>
<th>Project Number</th>
<th>Project Title</th>
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<tr>
<td>P54.001</td>
<td>Environmental and Economic Effects of a Potential National Retrofit of Closed-Cycle Cooling Systems</td>
<td>This project provides EPA, the public, and industry with technical information on the economic and environmental consequences of a potential CCC systems retrofit on power plants with once-through cooling systems. Specific products will be added pending EPRI's review of the content of the final Existing Facility Rule.</td>
</tr>
<tr>
<td>P54.002</td>
<td>Biological Sampling and Fish Health Assessment Research</td>
<td>This project provides information on impingement and entrainment survival sampling, mortality caused by the experimental sampling procedures, and benefit valuation. Products may be added as needed pending EPRI's review of the final EPA Existing Facility Rule, scheduled for release on July 27, 2012.</td>
</tr>
<tr>
<td>P54.003</td>
<td>Fish Protection Technology Research</td>
<td>This project will conduct laboratory and field research, gather information, and develop summaries of information on fish protection technology performance, operation, and maintenance. Additional products may be added as needed pending EPRI's review of the final EPA Existing Facility Rule.</td>
</tr>
<tr>
<td>P54.004</td>
<td>Thermal Discharge Risk Analysis</td>
<td>This project expands scientific and technical knowledge on thermal discharge effects and means to cost-efficiently address issues related to thermal discharge permits, regulations, and policies.</td>
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P54.001 Environmental and Economic Effects of a Potential National Retrofit of Closed-Cycle Cooling Systems (067512)

Key Research Question
On April 20, 2011, EPA released a proposed rule implementing the requirements of §316(b) of the Clean Water Act for existing facilities. A final Rule will be promulgated by July 27, 2012. In the proposed Rule, EPA noted that closed-cycle cooling (CCC) systems were not a national "Best Technology Available" for reducing adverse environmental impacts of cooling water intake structures; however, entrainment standards developed on a site-specific basis could require retrofits of CCC systems. In fact, as part of a potentially EPA-required Comprehensive Technical Feasibility and Cost Evaluation Study, the owner or operator of the facility must conduct a study to evaluate the technical feasibility of closed-cycle recirculating systems such as natural draft cooling towers, mechanical draft cooling towers, hybrid designs, and compact or multicell arrangements. Costs of retrofits, impacts to plant operations, environmental and social impacts, and potential impacts to system reliability may also need to be investigated if the Rule is promulgated as proposed.

Furthermore, although EPA rejected CCC as BTA and selected a regulatory option that provides for site-specific development of entrainment standards for protecting aquatic life, EPA did consider two options that included requirements for CCC, and one of these options could be adopted for the final Rule. Up-to-date scientific and engineering information on the potential ramifications of a CCC system retrofit, therefore, remains an important R&D issue to inform permit considerations and serve the public interest.

Approach
This project provides the public, industry, and EPA with technical information on the engineering, economic, and environmental consequences of a potential CCC systems retrofit on power plants with once-through cooling systems.
**Impact**

- EPRI research informs the permitting process with credible engineering and scientific information.
- EPRI research provides critical information on the overall costs, benefits, and impacts of a potential national retrofit of CCC on all power plants with once-through cooling. Such a retrofit could cost the industry from $50 billion to $100 billion; individual facility costs could range from $25 million to more than $1 billion. Retrofits could impact overall plant efficiency and electric system reliability as well as introducing environmental and social impacts of their own. EPRI’s research is providing documentation of these costs to support effective decision making, so the industry and individual facilities can plan accordingly if a retrofit alternative is pursued.
- EPRI research focuses on the engineering, scientific, and permitting issues that will need to be addressed as part of evaluating the technical feasibility of CCC as a site-specific BTA alternative.

**How to Apply Results**

Members can review EPRI’s information on CCC to support development of compliance strategies and completion of technical studies that will be required when the Rule is promulgated in 2012. EPRI’s engineering, scientific, and permitting information resulting from this project will be critical toward cost-effectively completing required permit applicant studies.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Closed-Cycle Cooling Retrofit Technical Resource Document</strong>: The EPA proposed Rule implementing §316(b) requires facilities withdrawing actual intake flows of more than 125 MGD to prepare a Comprehensive Technical Feasibility and Cost Evaluation Study and a Non-water Quality and Other Environmental Impacts Study. These studies require an engineering assessment of the technical feasibility and incremental costs of candidate entrainment mortality control technologies, including the technical feasibility, cost, environmental and social impacts, and impacts to plant economics and electric system reliability of closed-cycle recirculating systems. In 2012, EPRI will begin to assemble technical information to support the completion of these study requirements. Project content will be adjusted pending EPRI’s review of the final EPA Existing Facility Rule, scheduled for release on July 27, 2012.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

**Future Year Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Closed-Cycle Cooling Retrofit Technical Resource Document</strong>: The content of the final resource document to support analysis of the feasibility, cost, and impacts of CCC systems as part of evaluating site-specific technology options for reducing entrainment mortality will be determined following EPRI’s review of the final EPA Existing Facility Rule.</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>

**P54.002 Biological Sampling and Fish Health Assessment Research (100033)**

**Key Research Question**

Compliance with Clean Water Act §316 regulations requires sampling of fish and shellfish in the aquatic environment in the vicinity of cooling water intakes and discharges, as well as off of intake structures and within power plant cooling water systems. Water body type (for example, reservoir, estuary, and river), power plant cooling system configuration and operation, and intake fish protection technology all present site-specific
challenges to collecting representative sample data. The health of impinged and entrained fish can also further compromise the interpretation of sample results and fish protection technology performance. The proposed 2011 EPA Existing Facility Rule implementing §316(b) requires several applicant studies related to characterizing impingement and entrainment, as well as many future technology performance monitoring studies, which, if promulgated as proposed in the Final Rule, will be a challenge for permit applicants and permit authorities and may raise questions by the public at large. This project will provide the requisite learning to assist permit applicants, resource agencies and regulators, and the public in conducting technically sound sampling programs and interpreting the results.

Approach
Building on its past work in impingement, entrainment, and fish population and community sampling and assessments, this project will continue to improve and develop technical resources to support member compliance with the provisions of the §316(a) and (b) regulations. Most importantly, the research will be directed at the development of information to support preparation of site-specific technology performance verification monitoring plans.

Impact
• Supports strategic and cost-effective §316(a) and (b) compliance planning
• Defrays or avoids research costs that could exceed half a million dollars if funded individually

to Apply Results
The information developed in this program will be used by power plant environmental affairs and compliance staff and by federal and state §316 permit writers when developing permit compliance and monitoring plans. Staff members will read reports and disseminate information to community water resource stakeholders and government agencies. EPRI staff will provide company-specific compliance support through supplemental projects.

2012 Products

<table>
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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Verification Monitoring Technical Resource Document: Final procedures and technical information for verifying the performance of fish protection technologies will be included in this final report.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Benefit Valuation Technical Resource Document: The EPA proposed Existing Facility Rule requires plants with actual intake flows of more than 125 MGD to complete and submit a Benefit Valuation Study. This study requires an evaluation of the magnitude of water quality benefits, both monetized and nonmonetized, of the candidate entrainment mortality reduction technologies and operational measures evaluated, including but not limited to the incremental changes in the numbers of fish and shellfish, for all life stages, lost due to impingement and entrainment mortality; identification of the basis for monetized values assigned as a result of estimated changes in recreational and commercial species; recent mitigation efforts; identification of other benefits to the environment and local communities; and peer review. This project will update EPRI's 2006 technical resource document (1008473) on benefit valuation in accordance with requirements in the final Rule after its release in July 2012.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
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</table>
P54.003 Fish Protection Technology Research (SP0473)

Key Research Question
Identification of cost-effective fish protection technologies for installation at cooling water intake structures to control impingement and entrainment of fish and shellfish is a primary goal of industry in seeking to comply with Clean Water Act §316(b) New (Phase I) and Existing (Phase II) Facility rules. EPA released a proposed Rule for existing facilities on April 20, 2011, and a Final Rule will be released on July 27, 2012. The proposed Rule requires power plants with design intake flows exceeding 2 MGD to reduce impingement mortality by either reducing cooling water intake structure design through-screen velocity to less than 0.5 fps, or meeting an impingement mortality performance standard not to exceed 12% annual average and 31% monthly average. EPA identified modified ("fish-friendly") traveling water screens with 3/8 inch mesh as BTA for meeting the impingement mortality standard. Although the proposed Rule is unclear, alternative technologies such as behavioral systems, louvers, barrier nets, and wedge-wire screens that can meet equivalent impingement mortality reduction performance are also expected to be acceptable. Facilities with design intake flows exceeding 2 MGD are also subject to reducing entrainment mortality; however, only facilities withdrawing more than 125 MGD actual intake flow must submit a Comprehensive Entrainment Characterization Study, evaluate entrainment reduction technologies (including closed-cycle cooling), and evaluate their environmental impacts and benefits (nine specific factors must be evaluated). Compliance is determined by the permitting authority on a case-by-case basis and could result in a determination ranging from the existing cooling water intake structure being deemed BTA to a requirement to retrofit with closed-cycle cooling.

Approach
This project will evaluate various screen systems (coarse- and fine-mesh rotary screens, band screens, modified Ristroph screens, and wedge-wire screens), vacuum pump systems, and behavioral deterrent systems for performance relative to the proposed EPA 316(b) Existing Facility Rule impingement and entrainment reduction standards. This project will also investigate methods and costs for attaining a design intake velocity of less than 0.5 fps as well as its cost relative to costs associated with installing intake technologies such as traveling water screens. The latter could require expensive performance monitoring until the plant retired if the Rule is promulgated as proposed. Technology design, construction, O&M requirements, and costs will also be addressed in the evaluations conducted.

Impact
- Cost-effective §316(b) compliance planning
- Defrayed or avoided technology research costs that could exceed half a million dollars if funded individually

How to Apply Results
The information developed in this project will be used by power plant environmental affairs and compliance staff and by federal and state §316 permit writers when developing permit compliance and monitoring plans. Staff members will read reports and attend EPRI scheduled workshops and symposia to better understand the results and then disseminate information to community water resource stakeholders and government agencies. EPRI staff will provide company-specific compliance support through supplemental projects.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td>Fish Protection Technology Manual: Compliance with Clean Water Act §316 regulations requires sampling of fish and shellfish in the aquatic environment in the vicinity of cooling water intakes and discharges, as well as off of intake structures and within power plant cooling water systems. Water body type (for example, reservoir, estuary, and river), power plant cooling system configuration and operation, and intake fish protection technology all present</td>
<td>12/31/12</td>
<td>Technical Report</td>
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</tbody>
</table>
site-specific challenges to collecting representative sample data. The health of impinged and entrained fish can also further compromise the interpretation of sample results and fish protection technology performance. The proposed 2011 EPA Existing Facility Rule implementing §316(b) requires several applicant studies related to characterizing impingement and entrainment, as well as many future technology performance monitoring studies, which, if promulgated as proposed in the Final Rule, will be a challenge for permit applicants and permit authorities and may raise questions by the public at large. This project will provide the requisite learning to assist permit applicants, resource agencies and regulators, and the public in conducting technically sound sampling programs and interpreting the results.

**Laboratory and/or Field Evaluation of the Performance of a Technology for Reducing Entrainment Mortality:** This research, subject to EPRI Technical Advisory Committee review and prioritization, will continue EPRI's assessment of the performance of technologies, such as fine-mesh traveling screens and narrow-slot wedge-wire screens, for reducing entrainment of the early life stages (eggs, larvae, and juveniles) of fish and shellfish. Performance testing may continue in a laboratory flume, similar to testing EPRI has conducted on fine-mesh screen designs since 2008, or may move to pilot-scale field assessments. The objective is to continue to develop a robust performance database that funders may use to support expected future performance study reports required in permit applications.

### P54.004 Thermal Discharge Risk Analysis (102877)

**Key Research Question**
As a result of recent extended droughts in many areas of the country, increased societal demands for water withdrawals, continued concern about protection of aquatic biota, and growing demand for more electric power, there is renewed interest in the management and consequences of thermal discharges. In the fall of 2007, the EPRI-organized Second Thermal Ecology and Regulation Workshop was held at Tri-State Generation’s headquarters in Westminster, Colorado. The workshop drew about 120 domestic and international participants. Key topics of discussion included the convergence of thermal discharge issues with other issues such as §316(b), total maximum daily loads (TMDLs), effluent guidelines, water availability, and climate variability; the need to reconcile field and laboratory observations of fish response; interactions of thermal discharges with other pollutants; and responses of macroinvertebrates.

**Approach**
This project will provide research and information transfer that will improve the ability to cost-effectively obtain thermal discharge permits and comply with thermal discharge regulations. Research will focus on resolving discrepancies in the observed behavior of fish under laboratory and field conditions. Information transfer will involve EPRI's web-based document on thermal discharges (eTherm) and the publication of the results of EPRI's Third Thermal Ecology Conference, held in the fall of 2011.

**Impact**
- Supports strategic and cost-effective §316(a) compliance planning
- Provides credible technical information to EPA, state permitting and resource agencies, industry, and the public on thermal issues
- Defrays or avoids research costs that could exceed half a million dollars or more if funded individually
How to Apply Results

The information developed in this project will be used by power plant environmental affairs and compliance staff and by federal and state §316 permit writers when developing permit compliance and monitoring plans. Members will read reports and disseminate information to community water resource stakeholders and government agencies. EPRI staff will provide company-specific compliance support through supplemental projects.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Field Response of Fish to Thermal Plumes - Year One: Supports strategic and cost-effective §316(a) compliance planning</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td>Provides credible technical information to EPA, state permitting and resource agencies, industry, and the public on thermal issues</td>
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<tr>
<td>Defrays or avoids research costs that could exceed half a million dollars or more if funded individually</td>
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State of the Issue Document: Based on the Third Thermal Ecology and Regulation Workshop and other source material from eTherm, a synthesis of current understanding of the thermal discharge issue will be published. 12/31/12 Technical Report

Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Field Response of Fish to Thermal Plumes - Year Two: This is the second year of a three-year field experiment to demonstrate an experimental design to clarify why fish in the field appear to be more tolerant of thermal discharges than predicted by laboratory experiments. The study will focus on how the mobility of fish mediates responses to thermal plumes. The study will make use of sensors for tagging fish to track movement and temperature exposure. The study will consider thermal acclimation, thermal recovery, and thermal refugia.</td>
<td>12/31/13</td>
<td>Technical Resource</td>
</tr>
</tbody>
</table>

Update of Web-Based Thermal Reference: Based on input from the Third Thermal Workshop, government agencies, program advisors, and other sources, EPRI's web-based thermal reference, eTherm, will be updated and expanded. 12/31/13 Technical Resource

Field Response of Fish to Thermal Plumes - Year Three: This report will summarize a three-year field study to demonstrate an experimental design to clarify why fish in the field appear to be more tolerant of thermal discharges than predicted by laboratory experiments. The study will focus on how the mobility of fish mediates responses to thermal plumes. The study will make use of sensors for tagging fish to track movement and temperature exposure. The study will consider thermal acclimation, thermal recovery, and thermal refugia. 01/31/14 Technical Report

Fourth EPRI Thermal Ecology and Regulation Workshop: Fourth in a series of EPRI workshops to review and update recent research, monitoring, and regulatory developments since the last workshop in 2011. Over 100 attendees from government, power companies, consulting organizations, and academia are expected to participate in this two-day meeting, which will be hosted by an electric power company. 12/31/15 Technical Resource
Supplemental Projects

316(b) Fish Protection Compliance Strategies (072033)

Background, Objectives, and New Learnings

The electric power industry has a large fleet of existing plants that will be affected by the final Rule. EPA’s proposal will require all generation facilities withdrawing more than 2 million MGD, including those with closed-cycle cooling, to meet stringent impingement mortality reduction requirements. Once-through cooled units withdrawing more than 2 MGD are also subject to entrainment mortality reduction requirements, however, only those withdrawing more than 125 MGD actual intake flow are required to submit extensive information on entrainment mortality reduction technologies.

This decision analysis project will assist power companies in selecting cost-effective, technologically appropriate, scientifically logical, and environmentally protective approach for compliance with the impingement mortality reduction standards; in budgeting for initial information and study requirements; and in providing key technical information required within six months of the final Rule.

The proposed EPA Rule requires all electric generating facilities to reduce impingement mortality using one of two options: biological monitoring to verify impingement mortality does not exceed 12% annually and 31% monthly, or reduce the maximum through-screen design velocity so it does not exceed 0.5 fps. Additional requirements apply if 0.5 fps exists or is attained and there is potential for fish entrapment; for facilities withdrawing from oceans or tidal waters, there are additional requirements for shellfish protection. For the vast majority of facilities, the impingement reduction requirements will mean making significant modifications to the design and operation of the cooling water intake structure.

Facilities must submit key information within six months of the effective date of the final Rule, including an Impingement Mortality Reduction Plan (3.5 years allowed for final plan). Entrainment mortality reduction is determined on a case-by-case basis with a significantly longer period to submit information, with the exception of the entrainment mortality data collection plan. The flexibility provided in the Rule offers tremendous potential for the industry to optimize compliance for each site, with associated cost savings. But incorrect assumptions or decisions could also lead to significant cost penalties and/or technologies that fail to meet the prescriptive impingement mortality reduction requirements. Developing compliance option information and decision tools will support the selection of the most cost-effective solution(s) for each site.

Project Approach and Summary

This collaborative project, led by a team of EPRI and industry experts, proposes to support companies in selecting the most cost-effective means to meet the impingement mortality reduction requirements for each facility, estimate financial exposure, estimate technological exposure, budget for initial compliance requirements, and support development of initial submittal information. As a result of the nature of the specific requirements and the relatively short time allowed for option selection and information submittal, the project will focus primarily on the criteria that most affect impingement mortality reduction requirements. Specific new learning will occur based on the evaluation of site-specific locations. The project approach will involve use of site-specific information to create a decision tree analysis of potential outcomes, based on the best science and technological advancements found in the literature or in practice or recommended to the industrial community; on EPRI technical information; on site visits; and on a webcast on implications of the final Rule.

Risk Exposure – EPRI has developed extensive data on the costs of closed-cycle cooling retrofits and other entrainment reduction technologies as well as their potential benefits. Using the most appropriate impingement mortality reduction technologies and selection process may lead to significant economic risk exposure. Participating facilities will be provided with preliminary cost estimates for entrainment compliance for use in Form 10K reporting, strategic planning, or both.
**Impingement Mortality Reduction Option Selection** – Each facility will need to select an impingement mortality reduction compliance option using a decision tree, and a reasonable estimate of the cost of those options is critical to making a cost-effective selection. EPRI, using a combination of a site visit to acquire engineering design and hydraulic operating information and its experience in fish protection technology research, will identify practical alternatives and their costs for participating facilities. During the site visit EPRI will meet with company and facility personnel to discuss preliminary findings and address questions on the proposed Rule.

**Information Submittal Support** – The proposed Rule at section 122.21(r)(7) requires submittal of performance studies based on existing information. EPRI will prepare a report documenting available performance study information that can be used to meet this requirement. EPRI will also provide facilities with budget estimates for information and study requirements for the first 3.5 years.

**Webcast** - EPRI will conduct a webcast in the late fall of 2012 after the final Rule is issued. The workshop will cover changes in the final Rule and technical issues raised as well as overall findings of the 2012 research.

**Benefits**

EPA will finalize its 316(b) rule for existing facilities by July 27, 2012. The proposed Rule provides a clear indication of potential requirements for compliance in the final Rule. EPRI research will help companies better manage impingement and entrainment issues, which have an additional public benefit of preserving fish populations. This work helps electric power companies and the public understand how plants might be causing adverse environmental impacts and allow for the most economic compliance options. This research assists companies in planning a cost-effective compliance strategy and timely submittal of documents within six months of the effective date of the final Rule. This work will

- aid companies in estimating financial compliance exposure,
- provide guidance on selection of the most cost-effective options for impingement mortality reduction compliance,
- provide assistance in budgeting for compliance, and
- provide performance study information.
Water Availability and Use - Program 55

Program Overview

Program Description

Water is a shared resource critical to economic and community vitality. Population increases coupled with regional population shifts and competing demand among municipalities, agriculture, and industry are focusing more attention on water availability and are putting pressure on the electric power industry to increase its water use efficiency and minimize overall water use. Other contributing factors are climate variation and increased demand for aquatic ecosystem protection. In addition, water availability is a critical element of power plant siting processes. Agencies at the federal, regional, state, and local levels are increasing scrutiny of water resource use and developing long-term water allocation plans for both typical climate scenarios and severe drought. The power sector is also receiving increased scrutiny of its water use by financial institutions and investors. This scrutiny has significant implications for generation and transmission operations and growth. An integrated approach to developing water and energy infrastructures will be an important aspect of future water and electric power policy and regulation.

The Electric Power Research Institute's (EPRI's) Water Availability and Use Program helps industry, regulators, and other water resource stakeholders develop and implement cost-efficient, risk-based strategies for improved power plant water use efficiency, reduced power plant water demand, and management of climate variability impacts. The research focuses on developing and evaluating water resource management and forecasting tools, integrated engineering/economic risk management plans, nontraditional water resources, and advanced cooling technologies.

Research Value

This program prepares electric power companies to participate in evolving water and electric power policy development and build strategies for the future. Because water is a shared resource, the industry must understand the perspectives of all water resource stakeholders (government and nongovernment) and participate in stakeholder consensus decision making. If existing power plants cannot meet water needs, power companies may be forced to reduce power output or shut down these plants. Siting and construction of new generation capacity may be stalled by water availability constraints. This research helps power generators address

- a future where water use (including withdrawals, consumption, storage, and flow regulation) may be constrained by water availability,
- risk management associated with climate variability implications for water resource availability, and
- innovative technologies to increase water use efficiency and freshwater conservation through advanced cooling technologies and use of nontraditional water resources.

Approach

The program delivers scientific information, practical guidance, proven decision-support tools, innovative technologies, and technology assessments. Program information and research results are disseminated through reports, papers, webcasts, briefs, and presentation materials. The program delivers

- decision-support tools for water resource use management, development of water resource knowledge bases, and integrated sustainability assessments of regional power and water supply;
- guidelines, tools, and information to develop and evaluate advanced cooling technologies;
- strategies for and information on use of nontraditional water resources, such as sewage treatment plant discharge, saline groundwater, produced water from oil and natural gas extraction, agricultural drainage, and stormwater runoff;
• evaluation of new, innovative technologies to reduce freshwater resource use for electric power generation;
• data, information, and tools for comparative evaluations of power plant water conserving technologies for specific applications; and
• efficient water resource management for maintenance and growth of electric power generation capacity.

Accomplishments

For the last decade, EPRI has been a leader in creating and communicating understanding of the emerging issue of energy/water sustainability. EPRI has published more than 20 technical reports on the subject, covering research needs, national water availability assessments, water resource risk management methodologies, and technical evaluations to reduce power plant water use. EPRI has played a key role in numerous professional society, foundation, and government workshops and conferences to address the energy/water nexus. Existing EPRI research suggests that facility-specific savings can range from tens of thousands to tens of millions of dollars. Program accomplishments include

• engineering and economic analyses of advanced cooling technologies and use of nontraditional water sources;
• analyses of trends in water resource quantity and quality, along with implications for the electric power sector;
• national assessment of water availability for thermoelectric power generation;
• assessment of stormwater use by thermoelectric generation; and
• management and assessment methodologies for energy/water sustainability.

Current Year Activities

Program R&D for 2012 will address application of a cross-sector risk framework for managing water availability, stormwater power plant applications, water benchmarking for individual power plants, and evaluation/development of generation plant water balance tools. This program’s base-funded research agenda is closely integrated with research in the Technical Innovation (TI) program and the cross-sector supplemental project on Advanced Water-Conserving Cooling Technology (ACT). ACT conducts demonstrations and pilots of technologies with potential to reduce power plant freshwater use. TI conducts proof-of-concept studies of novel technologies to reduce power plant water use. Results from both TI and ACT feed into the Water Availability and Use base program, which evaluates their efficacy in meeting community and regional electric power/water resource sustainability. Specific program efforts will include

• testing of a new decision-support methodology, Water Prism, to assess and manage regional water resources, forecast water availability and shortages, and evaluate alternative multisector water use reduction strategies and technologies;
• a case study using results from an earlier EPRI study on stormwater characterization, effluent limits, treatment, and potential reuse at generation plants;
• completion of a study to make available analytic tools to conduct plant and site water balances; and
• completion of a study to develop and demonstrate an approach for electric power companies to benchmark water use.

Estimated 2012 Program Funding

$1.5M

Program Manager

Robert Goldstein, 650-855-2154, rogoldst@epri.com
Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>P55.001</td>
<td>Water Resource Management and Forecasting</td>
<td>This project addresses the need to develop and evaluate new strategies for managing water resources to guarantee water availability to meet current and future electric power demand.</td>
</tr>
<tr>
<td>P55.002</td>
<td>Integrated Engineering/Economic Analyses</td>
<td>This project conducts engineering and economic analyses of new, innovative water-saving technology applications.</td>
</tr>
<tr>
<td>P55.003</td>
<td>Nontraditional Water Use</td>
<td>This project evaluates new nontraditional water source use technologies to reduce freshwater use by power plants.</td>
</tr>
<tr>
<td>P55.004</td>
<td>Advanced Cooling Technologies</td>
<td>This project evaluates new cooling technologies to increase thermoelectric power plant water use efficiency.</td>
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P55.001 Water Resource Management and Forecasting (058353)

Key Research Question

Rapidly growing demand for clean, fresh water, coupled with the need to protect and enhance the environment, have made many areas of the United States vulnerable to water shortages. Such shortages could cause reductions in current supplies of electricity and could have direct impacts on power system planning and expansion. Water and energy shortages can occur relatively suddenly and can have adverse impacts on local and regional economies. To address this critical issue, research needs include creation and demonstration of decision-support tools for watershed management and power plant water use, development of water resource knowledge bases, and integrated sustainability assessments of regional power and water supply.

Approach

This project evaluates and creates planning strategies to address current and future water availability constraints on electric power generation. The project provides data, information, and tools to analyze and project water demand and supply within watersheds and regions under multiple future scenarios, including population and economic growth, land use change, new-technology development, and climate variability. The research also analyzes alternative management plans, including siting and design of new plants and retrofits of existing plants, for increased water use efficiency and minimization of water use.

Impact

- Develops cost-effective business strategies to address current and future water availability limitations
- Provides strategies for increased water and energy use efficiency, water conservation, and cost savings
- Leverages government-funded research to address industry needs
- Leverages public water supply and wastewater treatment sector–funded research

How to Apply Results

Power company environment, generation, and planning staff will extract information from project reports, papers, issue briefs, and presentation material. This information will also be disseminated to community water resource stakeholders and government agencies. Members will use results to support decision making with respect to meeting community and government pressures to increase water use efficiency and reduce water use in both existing and new plants. Members will use results to guide design and siting of new generation. In addition, EPRI will facilitate broader use and awareness of the results by presenting webcasts; briefing key stakeholders, including the U.S. Environmental Protection Agency (EPA) and state agencies; developing materials for the trade press/media; and continuing service on various government, academic, and professional organization advisory panels.
### 2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Water Prism Development - Year Three:</strong> This report will describe year three of the</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<td>development and testing of a new risk management decision support model to allow the</td>
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<td>evaluation of alternative cross-sector strategies and technology implementation to meet</td>
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<td>individual and collective water needs of the electric power, municipal, industrial, and</td>
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<td>agriculture sectors, as well as the aquatic ecosystem. This year, the study will</td>
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<td>complete the second test case study to test Prism functionality. The study is being</td>
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<td>conducted in the Southeast.</td>
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### Future Year Products

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<tr>
<td><strong>Water Conservation/Energy Efficiency Relationships - Year One:</strong> This project is the</td>
<td>12/31/13</td>
<td>Technical Resource</td>
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<td>first year of a two-year study to assess the energy efficiencies that can be obtained</td>
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<td>from water conservation strategies and technologies applied by other sectors, such as</td>
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<td>industry, public use, and agriculture. The results of the first year's work will be</td>
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<td>communicated to members through a webcast.</td>
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| **Regional Water Management Analysis - Year One:** Previous Water Prism case studies      | 12/31/13                | Technical Resource    |
| focused on testing its functionality and were limited to the Midwest and Southeast. The  |                         |                      |
| objective of this study is to illustrate full assessment/management/planning applications within a diverse set of geographical regions. The first year of regional assessments of available water under alternative future management scenarios will be conducted using Water Prism. Scenarios will include increasing energy demands, increasing population, drought, advanced water saving technologies, and water conservation strategies. Analyses will be performed for contrasting environmental regions. |                         |                      |

| **Regional Water Management Analysis - Year Two:** During the development phase of      | 08/31/14                | Technical Report      |
| Water Prism, case studies focused on testing its functionality and were limited to the   |                         |                      |
| Midwest and Southeast. The objective of this study is to illustrate full assessment/management/planning applications within a diverse set of geographical regions. The second year of the regional water management analysis will expand on scenarios and geographical regions used in the previous year. Scenarios will include increasing energy demands, increasing population, drought, advanced water saving technologies, and water conservation strategies. Analyses will be performed for contrasting environmental regions. |                         |                      |

| **Water Conservation/Energy Efficiency Relationships - Year Two:** This project is the   | 12/31/14                | Technical Report      |
| concluding year of a study to assess the energy efficiencies that can be obtained from   |                         |                      |
| water conservation strategies and technologies applied by other sectors, such as industry, |                         |                      |
| public use, and agriculture.                                                         |                         |                      |

### P55.002 Integrated Engineering/Economic Analyses (070656)

#### Key Research Question

Rapidly growing demand for clean, fresh water, coupled with the need to protect and enhance the environment, have made many areas of the United States vulnerable to water shortages. Water and energy shortages can occur relatively suddenly and can have adverse impacts on local and regional economies. There are existing...
technologies related to air cooling, water recycling, nontraditional water use, and thermal conversion efficiency improvement that can be applied today to increase power plant water use efficiency and overall water conservation; however, these technologies have significant energy and dollar costs, as well as other issues. Research is being conducted by EPRI and other organizations to create, develop, and demonstrate new technologies that will reduce costs and limitations and improve performance (see projects 55.00 and 55.004). Technology performance and cost are dependent on location and plant type; hence, there is a need to create a technology tool box that allows members to compare relative water saving technology strengths and weaknesses for specific applications, for both new plants and retrofits. Research is also needed to evaluate gains in energy efficiency that can be achieved by improving water use efficiencies in economic and social sectors other than the electric power sector.

Approach

The project provides data, information, and tools to conduct comparative engineering/economic evaluations of power plant water-conserving technologies for specific applications. This work involves creation and testing of web-based reference material and analytic methods to provide engineering reliability and lifetime and economic evaluations that consider capital, operating, and maintenance costs. Consideration is also given to ease and cost of retrofit as anticipated technological advances occur. Web-based references will collect information not only on energy sector water-conserving technologies and strategies but also on water-conserving technologies and strategies of other sectors and on the associated energy savings.

Impact

- Based on site characteristics and generation technology, evaluates comparative strengths and weaknesses of alternative water-conserving technologies
- Provides guidance for cross-sector collaboration to increase energy and water use efficiencies

How to Apply Results

Power company environment, generation, and planning staff will extract information from project reports, papers, issue briefs, and presentation material. This information will also be disseminated to community water resource stakeholders and government agencies. Members will use results to support decision making with respect to selecting technologies to improve water use efficiency and reduce freshwater use. Members will use results to guide design of new generation and retrofitting of existing generation. In addition, EPRI will facilitate broader use and awareness of the results by presenting webcasts; briefing key stakeholders, including EPA and state agencies; developing materials for the trade press/media and the public; and continuing service on various government, academic, and professional organization advisory panels.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Water Benchmarking - Year Two:</strong> This product is jointly funded with the Council of Great Lakes Industries (CGLI) and the National Council of Air and Stream Improvement (NCASI). Water benchmarks proposed by a diverse group of organizations will be reviewed to determine best features. The results will be used to develop a highly robust benchmark, which will be tested on a variety of facilities: a thermoelectric generating plant, a paper mill, a cement plant, and an oil refinery.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Plant Water Budget - Year Two:</strong> This report will document completion of evaluation of alternate approaches to conducting a power plant water budget. This work is cosupported by the cross-sector Advanced Water-Conserving Cooling Technology supplemental project and the Effluent Guidelines Program.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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### Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Water Technology Summary Reference - Year One:</strong> This is the first year of a two-year study to evaluate current information on cost, optimization, and operational and maintenance issues related to use of advanced cooling and freshwater conservation techniques in electricity generation. This reference will provide the latest information in design, case studies, new technologies, guidance, and cost-benefit analysis. The reference will be web-based to allow for easy updating.</td>
<td>12/31/13</td>
<td>Technical Resource</td>
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<tr>
<td><strong>Water Technology Summary Reference - Year Two:</strong> This is the second year of a two-year study to evaluate current information on cost, optimization, and operational and maintenance issues related to use of advanced cooling and freshwater conservation techniques in electricity generation. This reference will provide the latest information in design, case studies, new technologies, guidance, and cost-benefit analysis. The reference will be web-based to allow for easy updating.</td>
<td>12/31/14</td>
<td>Technical Resource</td>
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**P55.003 Nontraditional Water Use (070655)**

**Key Research Question**

Thermoelectric power plants need sufficient water supplies to meet generation demands. Most of the water used by thermoelectric power plants is fresh water. Power companies are experiencing growing pressure to reduce their freshwater use. One strategy for accomplishing this goal is to use nontraditional sources of water, such as sewage treatment plant discharge, saline groundwater, water produced in association with oil and gas extraction, agricultural drainage, and stormwater runoff. There is also potential for generating plants to recycle their own wastewater streams. The use of nontraditional water sources may require pre- or post-use water treatment, reduction of cycles of concentration, or, in the case of retrofits, replacement of existing cooling system materials. Hence, nontraditional water sources have energy and dollar costs associated with their use that go beyond those for freshwater use. There is a need to create and test new technologies to decrease these costs. Research needs include improving desalination systems by development of increased membrane transport efficiencies, increased salt rejection, decreased membrane scaling and fouling, and improved semipermeable membranes for forward osmosis.

**Approach**

By creating new knowledge bases and conducting case studies, this project provides guidelines, strategies, tools, and information for use, and for dollar- and energy-cost optimization, of nontraditional water sources to meet water conservation requirements of permits, regulations, and policies. The project addresses siting and construction of new plants and retrofitting of existing plants. This project is closely integrated with the cross-sector supplemental project on advanced cooling technologies and the Technology Innovation project on novel water-saving technologies. The supplemental project focuses on technologies that are far advanced with respect to development and are either ready or nearly ready for demonstration and pilot testing. The Technology Innovation project focuses on technologies that are in the discovery or early-development stages.

**Impact**

- Reduces impacts of nontraditional water sources on power plant performance and O&M costs
- Expedites permitting by providing guidelines, tools, strategies, and information for the use and optimization of nontraditional water sources to meet water conservation requirements
- Evaluates innovative freshwater-conserving technologies for use at thermoelectric power plants
How to Apply Results

Power company environmental and generation staff will apply project results to evaluate the use of nontraditional water sources to reduce water consumption for cooling and other power plant needs, thus reducing vulnerability to future water shortages. U.S. Department of Energy and vendor cost sharing will be solicited. Workshops and webcasts will be held to foster communication of results to members, vendors, and government agencies.

2012 Products

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<tr>
<td><strong>Stormwater Use Case Studies - Year Two</strong>: This project is the second year of a two-year study. The study will use results from an earlier EPRI study on stormwater characterization, effluent limits, treatment, and reuse to assess stormwater use at specific power plants. Case studies will be chosen to represent different geographical regions and different generation types.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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Future Year Products

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<tr>
<td><strong>Innovative Desalination Technologies - Year One</strong>: This is the first year of a two-year study to evaluate the latest research and application results regarding the use of nontraditional water sources and water recycling for power plant use.</td>
<td>12/31/13</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Innovative Desalination Technologies - Year Two</strong>: This is the second year of a two-year study to evaluate the latest research and application results regarding the use of nontraditional water sources and water recycling for power plant use.</td>
<td>12/31/14</td>
<td>Technical Report</td>
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P55.004 Advanced Cooling Technologies (063345)

Key Research Question

Thermoelectric power plants need sufficient water supplies to meet generation demands. Most of the water used by thermoelectric power plants is either withdrawn for once-through cooling or consumed by wet-cooling towers. Pressure on the electric power industry to reduce water withdrawal and consumption will continue to increase over the next quarter-century as a result of greater demands for fresh water and electric power associated with population growth. Climate variability and growing concerns about environmental protection may exacerbate the situation. Existing technologies for significantly reducing cooling water withdrawal and consumption have significant energy penalties and high costs. Existing air-cooled condensers require large amounts of land and are subject to operating problems in high winds. The suitability of indirect air cooling for conventional nuclear power plants has yet to be demonstrated. There is a need to create, test, and demonstrate new technologies to increase power plant water use efficiency, especially for cooling.

Approach

By creating new knowledge bases, this project enhances compliance processes, controls O&M costs, reduces construction costs, expedites permitting, and assesses innovative, breakthrough technologies to increase cooling water use efficiency and reduce overall water use by power plants. The project provides guidelines, tools, and information for use and optimization of advanced cooling technologies to meet water conservation requirements of permits, regulations, and policies. The project also reduces costs and heat-rate penalties associated with advanced cooling technologies, and addresses siting and construction of new plants and retrofitting of existing plants. In addition to the research performed in this program, a related supplemental
Electric Power Research Institute 2012 Research Portfolio

Project on advanced cooling technologies (S55.001) focuses on technologies that are far advanced with respect to development and are either ready or nearly ready for demonstration or pilot testing.

Impact

- Reduces impacts of wet and dry cooling on power plant performance and O&M costs
- Expedites permitting by providing guidelines, tools, and information for the use and optimization of advanced cooling technologies to meet water conservation requirements
- Evaluates innovative water-conserving technologies for use at thermoelectric power plants

How to Apply Results

Power company environmental and generation staff will apply project results to evaluate alternative wet, dry, and hybrid cooling technologies to reduce water withdrawal and consumption for cooling, and hence vulnerability to future water shortages. Workshops and webcasts will be held to foster communication of results to members, vendors, government agencies, and the public.

Future Year Products

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<tbody>
<tr>
<td><strong>Advanced Cooling Technology Evaluation - Year One:</strong> This technical update will document the first year of a study to critically review existing and proposed advanced cooling technologies. The project will evaluate and synthesize research results derived from EPRI TI and supplemental projects (as well as other sources) on advanced cooling technologies. Technologies to be considered will include those in the conceptual stage, up to and including those that have already been implemented. Special attention will be paid to energy and dollar costs, strengths, and limitations. For those technologies still in the conceptual stage, time and dollars needed to bring to demonstration will be estimated, as well as critical technical challenges to successful implementation. The project will also review novel cooling approaches being used and studied in other industries, such as the computer, electronics, petrochemical, and pharmaceutical industries.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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| **Advanced Cooling Technology Evaluation - Year Two:** This report will document the second year of a study to critically review existing and proposed advanced cooling technologies. The project will evaluate and synthesize research results derived from EPRI TI and supplemental projects (as well as other sources) on advanced cooling technologies. Technologies to be considered will include those in the conceptual stage, up to and including those that have already been implemented. Special attention will be paid to energy and dollar costs, strengths, and limitations. For those technologies still in the conceptual stage, time and dollars needed to bring to demonstration will be estimated, as well as critical technical challenges to successful implementation. The project will also review novel cooling approaches being used and studied in other industries, such as the computer, electronics, petrochemical, and pharmaceutical industries. | 12/31/14 | Technical Report |
Supplemental Projects

Assessment of Water Availability Risk to Power Generation (072161)

Background, Objectives, and New Learnings
Along with other societal and economic sectors, electric power generators use significant quantities of water and therefore must manage the accompanying environmental, regulatory, reputational, and financial risks. Many technologies and strategies are available to the electric power, municipal, industrial, and agricultural sectors which potentially could be implemented to reduce freshwater use (especially under critical flow conditions) and help water users accommodate future demands. The establishment of a roadmap for meeting water demands under available water resources is not straightforward due to the many combinations of technologies and strategies that can be applied across sectors to achieve water savings. Assessment of water limitations to power generation and evaluation of benefits of multi-sector water saving strategies to reduce risk can be addressed through application of a unique decision support system (DSS) called Water Prism.

Water Prism uses a water balance approach to compute water demand within a watershed under current and projected “business as usual” conditions. A background watershed model and information regarding groundwater resources inform the Water Prism regarding available water resources supply. Water Prism also accounts for ecological flow limits within the system (e.g., minimum flows or reservoir levels). Data input requirements for the application of Water Prism include climate, land use, current water withdrawal and discharge records, and projected water demands.

Water Prism will support decision making for power plant siting and retrofit options by considering current and future electric power sector water demands and exploring opportunities with various generation types, advanced cooling technologies, non-traditional water sources, and in-plant water reuse. The tool will recognize watershed and regional hydrology characteristics, water demands of competing water resource stakeholders, and community water sharing strategies. Water Prism will help evaluate potential benefits of water risk reduction for the electric power and other sectors and represented through graphical output similar to EPRI’s Prism analysis (which focused on potential electricity sector greenhouse gas emission reductions).

Water Prism scenarios will be constructed to forecast water availability constraints for existing and proposed generation plants and evaluate how implementation of various water saving strategies may result in a shift of the demand curve so that water needs will be met within the bounds of available supply. Strategies may include opportunities within one or more sectors such as:

- Electric power –in-plant reuse, non-traditional water sources, advanced cooling technologies
- Agricultural –low water crops, water efficient irrigation, retirement of agricultural land
- Municipal – water efficient fixtures, low water landscaping, distribution system maintenance
- Industrial – non-traditional water sources, in-plant reuse, rainwater capture
- Ecosystem demand – flexibility within a range of ecosystem constraints

Benefits
This project will allow electric power companies as well as the public to assess risk of water shortages. The outcomes of this work will evaluate existing or planned generation, and alternative technologies and strategies for reducing that risk. It will also assist electric participants to better understand potential benefits of water saving technologies in all water using sectors within the context of available supply.
Advanced Water-Conserving Cooling Technologies (067744)

Background, Objectives, and New Learnings

The electric power industry requires reliable access to large amounts of water, primarily for cooling. Growing demand for electric power, coupled with growing water demand in agricultural, municipal, residential, commercial, and industrial sectors, could strain water supplies in the future. Facing increasing pressures to improve water conservation and reduce water consumption at power generation stations, the electricity industry is investigating new and innovative technologies. These technologies may be plant and location specific.

This project will accelerate industry activities aimed at building confidence in advanced cooling technologies to reduce overall water use for power production by new and operating units. EPRI technical products and targeted demonstration projects will help minimize implementation and deployment risks while minimizing individual company expenditures.

Project Approach and Summary

This collaborative project, led by a team of EPRI and industry experts, proposes a range of projects to develop, test, and deploy efficient advanced cooling technologies. The projects will focus primarily on technology development and testing, but will also provide related information on economics, performance optimization, risk management, improved decision making, and public acceptance. This work will include a thorough investigation of geographic and power plant-specific considerations. Examples include the following:

Power Plant Siting – The availability of cooling water will play an increasing role in the siting of new thermal electric power plants. This project uses GIS-based watershed cycling models to develop and test a protocol to evaluate alternative sites, cooling systems, and cooling water sources.

Meteorological Impacts on Air-Cooled Condensers (ACCs) – Extreme circumstances such as strong, gusty winds can cause an ACC to trip and can affect unit operations. EPRI has pinpointed the cause of these wind effects. A simple ACC design change can be field tested to prove mitigation potential.

Indirect Dry Cooling – Indirect cooling systems, which use a dry cooling tower to cool the water circulating through the condenser, are most adaptable to nuclear units with secondary cooling loops. This project will evaluate performance and cost data from indirect cooling installations worldwide.

Hybrid Tower Designs – There is very little public information on the design, cost, and performance of hybrid cooling systems. This project investigates new hybrid designs that may offer better performance and/or lower costs and provides guidelines for the specification, design, construction, and operation of hybrid systems.

Water Recovery Options – At least two new systems that capture water from cooling tower plumes and stack gases will be tested to collect performance and cost data.

Wet Surface Air Coolers – EPRI has demonstrated a pilot wet-surface air cooler (WSAC) at more than 50 cycles of concentration with fresh water. This project will demonstrate the use of WSAC with degraded water sources such as municipal effluent.

Advanced Bottoming Cycles – These cycles offer potential cooling capability while also increasing station efficiency. EPRI and other entities have studied these cycles (ammonia and supercritical carbon dioxide) for more than two decades, but further demonstration is needed before members can adopt them for new facilities.

Preserving Once-Through Cooling Options – Permitting new, once-through cooling will require technical justification that ecological impacts are lower than those of cooling towers.
Benefits

Pressures to reduce overall water withdrawal and consumption are no longer limited to arid parts of the world such as the western United States. More-temperate climates are experiencing water constraints as a result of population growth, precipitation fluctuations, and changing demand patterns. These pressures and associated operating challenges are expected to grow significantly as utilities seek to permit and build new generation facilities to meet growing electricity demand.
Program Description
The U.S. Environmental Protection Agency (EPA) is currently revising effluent guidelines for the steam electric power generating industry. EPA also issued an Information Collection Request (ICR) to obtain additional data concerning power plant water management as well as general facility information to support its rulemaking. As EPA moves forward with this process, the available data will be used to broadly characterize the applicability and costs for characterization of trace elements in power plant wastewater streams and to evaluate the overall performance and costs for wastewater treatment options for trace metals and nutrients. Science-based analyses and extrapolation of the data will be necessary to help inform the various stakeholders, including EPA, industry and the public. In parallel, some states and regions (such as the Great Lakes) are considering low parts-per-trillion limits for mercury, while some power plants are unable to achieve selenium permit limits based on traditional removal processes.

The Electric Power Research Institute’s (EPRI's) Effluent Guidelines and Water Quality Management program delivers credible data to characterize power plant wastewaters and conducts scientifically sound data interpretation to inform potential revisions to the effluent guidelines for the steam electric industry. The program also develops sound guidelines for effective management of low-volume, non-ash wastewater streams as well as ash pond chemistry and discharges, provides cost-effective and reliable options for wastewater treatment to remove chemicals such as trace metals, and develops practical tools for biofouling control using nontoxic alternatives to oxidizing biocides such as chlorine.

Research Value
Program research helps facility owners develop effective effluent guideline compliance strategies. As water discharge permit limits for trace metals and nutrients tighten, power companies require accurate analytical methods, reliable data, and independent, unbiased treatment performance and cost data. In addition, new flue gas desulfurization (FGD) systems may require wastewater treatment for mercury and selenium. Key motivations for this research include the following:

- The best scientific data available are needed for developing effluent guideline standards.
- Inaccurate analytical methods may lead to false permit violations, increased capital and operating/maintenance costs for wastewater treatment, and higher likelihood of permit violations.
- Additional water treatment may be required for plants to achieve ash ponds permit limits.
- Limited options exist for nonoxidizing alternatives to chlorine.

Approach
EPRI characterizes power plant waters, evaluates analytical methods, and independently evaluates water treatment performance and costs. Program results are communicated through briefings for key stakeholders, including regulatory and other government agencies; reports; presentation materials; information summaries for public consumption; and service on various advisory panels. This program delivers:

- industry-specific data and information that helps determine the need for effluent guideline revisions;
- independent evaluation of wastewater treatment systems including overall treatment performance and capital as well as operation and maintenance costs;
- strategies to ensure compliance with existing or revised discharge permits;
- guidance in managing low-volume wastewaters, including management after conversion to dry fly ash handling; and
- optimized ash pond management techniques that can avoid the need for costly chemical/physical wastewater treatment, which may cost tens of millions of dollars at individual power plant sites.
Accomplishments
The program's research informs industry, regulators, and other stakeholders about potential discharge limits and feasibility of treatment technologies as they relate to effluent guideline revisions. Program information has also been useful to power companies that install new FGD systems, negotiate new wastewater discharge permits, and plan water treatment and management options. Program accomplishments include

- evaluation of promising technologies for FGD wastewater treatment of mercury and selenium, including physical/chemical precipitation/adsorption, passive treatment, and anaerobic biological reduction;
- guidelines for passive treatment technologies for traditional wastewater constituents and some trace metals;
- screening data identifying FGD wastewater constituents of interest;
- laboratory evaluation of selenium chemistry in wet FGD systems;
- characterization of mercury in FGD waters and its potential treatment implications;
- characterization data and predictive tools for estimating trace metals in ash pond wastewater;
- guidelines for low-volume wastewater management of total suspended solids, pH, and trace metals;
- guidelines for optimizing ash pond management of total suspended solids and pH; and
- full-scale evaluation of a nonoxidizing alternative to chlorine for macrofouling control.

Current Year Activities
Program R&D for 2012 will continue to focus on mercury and selenium water characterization and treatment evaluation and will also begin to include other constituents of interest (such as arsenic, boron, and nutrients). Specifically, the research will

- characterize power plant wastewater, evaluate the impact of FGD systems on wastewater quality, and develop FGD water management options;
- assess and evaluate promising technologies that cost-effectively remove trace metals, including mercury and selenium, from power plant wastewaters;
- evaluate and assess the applicability, limitations, reliability, by-product management, and costs for zero liquid discharge (ZLD) approaches, including thermal evaporation;
- optimize water management options and costs for various scenarios, such as dry bottom and fly ash handling for the removal of solids as well as trace metals and nutrients;
- evaluate design considerations and implementation issues for conversion from wet to dry ash handling systems, and evaluate pond management of low-volume wastewater streams without fly ash sluice water; and
- evaluate alternatives to chlorine for micro- and macrofouling control.

Estimated 2012 Program Funding
$2.0M

Program Manager
Paul Chu, 650-855-2362, pchu@epri.com
## Summary of Projects

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P56.001</td>
<td>Wastewater Toxics Characterization</td>
<td>Trace metals (including mercury and selenium) and nutrients are characterized to understand how power plant operations impact trace metal fate and distribution in FGDs, ash ponds, and other wastewater streams. Accurate and reliable sampling and analytical methods are developed for these water matrices.</td>
</tr>
<tr>
<td>P56.002</td>
<td>Effluent Treatment Technology</td>
<td>The current evaluations focus on treatment approaches that are able to achieve low levels (parts per trillion) for mercury and to remove all forms of selenium (including selenate). Other trace metals (such as arsenic and boron) as well as nutrients will also be evaluated.</td>
</tr>
<tr>
<td>P56.003</td>
<td>Low-Volume Plant Wastewater</td>
<td>Tools and guidance documents for low-volume wastewater characterization and management will be developed to assist power plants in the integrated management, treatment, and recycle/reuse of various wastewaters.</td>
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<tr>
<td>P56.004</td>
<td>Ash Handling</td>
<td>Surveys of recent applications and evaluations of converting wet ash handling systems will provide a summary of industry experiences.</td>
</tr>
<tr>
<td>P56.005</td>
<td>Nonoxidizing Biocides for Biofouling Control</td>
<td>Pilot- and full-scale evaluations are being conducted at power plant waters to evaluate the efficacy of promising alternatives to chlorine.</td>
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### P56.001 Wastewater Toxics Characterization (101139)

#### Key Research Question

EPA recently issued an Information Collection Request (ICR) to support its effluent guidelines rulemaking for the steam electric industry. Scientifically sound analyses and interpretation of all the data are needed to support the stakeholder community in providing EPA with the best information available, allowing the Agency to recommend and potentially propose science-based regulatory guidelines. Power plants are installing new air pollution control technologies (wet FGD technologies, selective catalytic reduction [SCR] technologies, mercury controls), as well as changing coal types, which may impact power plant wastewater characteristics. Facilities need accurate data to clarify the impact of plant operational changes on wastewater so that, if necessary, they can implement cost-effective wastewater management options while complying with current permit limits and negotiating future permits.

#### Approach

This project will characterize power plant wastewater streams and develop wastewater management options to cost-effectively meet current and future permit limits. Specific project activities will

- characterize total, dissolved, and speciated trace metals (such as mercury and selenium) as well as nutrients in FGD waters and ash ponds, and evaluate the partitioning of trace metals in FGD systems;
- clarify the chemistry of selenium oxidation in wet FGD systems and optimize selenium wastewater management with sulfur dioxide treatment performance;
- characterize the chemistry and various species of mercury in FGD waters, as well as treatment implications;
- evaluate the impact of FGD on wastewater discharges and develop water management options; and
- evaluate and determine suitable sampling and analytical approaches for trace elements (including speciation for selenium) in power plant matrices, including FGD waters (a joint effort with Program 59, Power Plant Multimedia Toxics Characterization).
Impact

- Provides credible data analyses to inform the EPA effluent guidelines study
- Assists power plants with managing the impact of future air pollution controls (for example, FGD, SCR, sulfur trioxide mitigation, mercury controls) and coal switching on wastewater
- Improves risk management and supports development of science-based regulations
- Provides data for permit negotiations by developing predictive estimates for trace substance concentrations in wastewater, as well as developing toxics management options that could reduce environmental discharges and potentially reduce operating costs

How to Apply Results

Project findings and deliverables will be used by power company staff in environmental affairs/compliance in responding to EPA’s effluent guidelines study, so that stakeholders have sufficient high quality, accurate data. The project will also assist facilities in responding to permit negotiations with state and local agencies. The results will assist wastewater engineers and scientists in developing wastewater management options for new FGD systems, as well as in evaluating the potential impact of other power plant operations changes (such as coal changes). In addition, EPRI staff will facilitate broader use and awareness of the results by holding periodic briefings for key stakeholders, including regulatory and other government agencies; developing materials for the trade press/media and the public; and continuing service on various advisory panels.

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<tr>
<td>Evaluation of the Impact of Limestone Quality on Mercury and Trace Metals: This technical update will summarize laboratory studies to evaluate the effect of limestone chemical composition on concentrations of mercury, selenium, and other trace metals in FGD waters, as well as treatment implications.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Evaluation of Selenium Chemistry in Wet FGDs: This report will provide an update on EPRI field studies to characterize selenium chemistry and speciation in FGD waters, with the goal of optimizing FGD operations for selenium (and other trace metals) wastewater as well as sulfur chemistry.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P56.002 Effluent Treatment Technology (052395)

Key Research Question

Water discharge permits are becoming increasingly stringent, allowing for release of only very low concentrations of pollutants in plant effluents. This trend may accelerate, as EPA is expected to determine best available technology (BAT) and propose revised effluent guidelines by July 2012. As new air pollution controls (such as SCR systems and FGD systems) are installed, their impact on wastewater may require cost-effective and reliable technologies to remove trace metals and other compounds (such as mercury, selenium, arsenic, boron, total suspended solids, and ammonia). Some states require low parts-per-trillion mercury discharge levels, even though the commercially available technologies can achieve only parts-per-billion performance levels. Limited EPRI data suggest that several forms of selenium may be present in FGD wastewater; the treatment implications are under investigation. As more pollutants are potentially regulated at lower levels, the ability to discharge wastewater may become more difficult; thus, zero-liquid-discharge (ZLD) technology options need to be thoroughly evaluated to maintain operational reliability.
Approach
This project will assess and evaluate the performance, costs, and reliability of promising technologies that remove trace metals from power plant wastewaters. This activity will

- provide an informed, impartial third-party evaluation of commercially available wastewater treatment technologies;
- evaluate promising technologies to achieve low levels (parts per trillion) of mercury in effluents as well as technologies to cost-effectively remove all species of selenium (such as selenate);
- evaluate the factors that impact the capital and operating costs for treating FGD wastewater for solids and trace metals removal;
- evaluate integrated passive treatment systems for removing trace metals, including mercury and selenium from FGD and other plant wastewater;
- evaluate the applicability and limitations of ZLD approaches; and
- evaluate future priorities such as boron, arsenic, chloride, total suspended solids, ammonia, and other trace metals as the need arises.

Impact
- Provides scientifically sound and reliable performance and cost information to industry and all stakeholders to inform the rulemaking process
- Evaluates and provides cost-effective, reliable, environmentally protective wastewater treatment approaches and options to achieve increasingly stringent trace metal, inorganic, and organic effluent limits
- Reduces operations and maintenance costs for wastewater treatment technologies
- Enhances compliance
- Maintains overall plant reliability

How to Apply Results
Project findings and deliverables will assist power plant water engineers and scientists in providing wastewater treatment options for new FGD systems, ash ponds, and other low-volume waste streams. Power plants can participate in hosting pilot- and full-scale evaluations of promising wastewater treatment technologies. The results will also be employed by corporate environmental staff in responding to EPA’s effluent guidelines study. Information from this project will be communicated to regulatory agencies and other stakeholders at the state and federal levels through reports, information summaries, and briefings.

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<tr>
<td><strong>Water Treatment Technology Evaluation Report</strong>: Promising approaches for mercury and selenium water treatment will be evaluated in laboratory, pilot, and full-scale evaluations. The results will be summarized to present overall removal efficiencies, projected costs (where applicable), as well as future recommended R&amp;D necessary to properly evaluate the technology.</td>
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<td><strong>Zero Liquid Discharge (ZLD) Update</strong>: This report will document EPRI's continued evaluation of the applicability, limitations, and potential issues with thermal evaporation of wastewaters.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>
P56.003 Low-Volume Plant Wastewater (055830)

Key Research Question
Ash ponds are under increasing scrutiny and water discharge permits have become increasingly stringent, allowing for the release of only very low concentrations of pollutants in plant effluents. As power plants convert from wet ash handling to dry ash handling, pond management will shift to management of the various low-volume wastewater streams, without the ash sluice water. Power plants may choose to repurpose existing ponds or build new dedicated constructed treatment systems. Under either approach, tools will be necessary to help guide power plants in terms of characterizing the flows and constituents of these intermittent low-volume water streams.

Approach
This project will evaluate and develop integrated approaches for managing the various low-volume wastewater streams and for evaluating the benefits of recycling and reusing treated wastewater to minimize wastewater discharge flows. As power plants convert to dry ash handling, this project will optimize management of the remaining wastewater streams. Specific activities will

- evaluate costs and options for management of various low-volume wastewater streams, without ash sluice water, including both tank-based constructed treatment systems and repurposed existing ponds;
- provide guidance and tools to assist power plant personnel in characterizing flows and constituents in low-volume wastewaters; and
- evaluate recycle and reuse of treated plant wastewater within the power plant.

Impact
- Optimizes management and treatment of total suspended solids, pH, nutrients, and trace metals to meet discharge compliance limits at least cost
- Reduces operations and maintenance costs
- Enhances compliance to achieve stringent trace metal and organic effluent limits

How to Apply Results
Project findings and deliverables will be employed by wastewater engineers and scientists in developing wastewater management options for low-volume wastewater management, as well as evaluating the potential impact of plant operations changes (for example, coal changes, SCR and wet FGD additions). Periodic workshops will be used to facilitate broader use and awareness of EPRI results and provide forums for utilities to share experiences and results. Summary information will be provided to external stakeholders, including the public, so they are familiar with the technology and its advantages. Presentations and briefings will be provided as well.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
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<tbody>
<tr>
<td><strong>Low-Volume Wastewater Management Guidelines:</strong> This report will provide updated guidance to assist power plants in managing, treating, and recycling/reusing low-volume wastewater streams after the closure of ash ponds.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
P56.004 Ash Handling (067513)

Key Research Question
Some power plants may be required to evaluate alternatives to wet ash handling as regulatory pressures on ash pond discharges and constraints on water use and consumption become more stringent in the future.

Approach
This project will evaluate engineering design considerations and implementation issues for the conversion of wet ash handling systems to dry ash handling and semidry high-density slurry systems. The initial effort will consist of a survey of current alternative ash handling systems and issues with operation and maintenance.

Impact
- Reduces capital and operating costs in managing and transporting fly ash
- Minimizes operating and maintenance issues

How to Apply Results
Project findings and deliverables will be employed by water management staff in evaluating alternatives to dry ash handling. Results may assist in permit negotiations.

P56.005 Nonoxidizing Biocides for Biofouling Control (101136)

Key Research Question
Biofouling is the undesirable accumulation of microorganisms, plants, and animals on heat transfer surfaces such as condenser tubes. Managing biofouling is critical, as such accumulation reduces the heat transfer rate and can lead to materials corrosion. Biofouling also can lead to significant plant efficiency and availability problems unless it is controlled and managed. Chlorine is commonly used for biofouling control; however, chlorine use will likely become more limited in the future due to regulatory restrictions (for example, revised effluent guidelines). Alternative approaches are needed that will allow plants to maintain or improve efficient operations with lower maintenance costs.

Approach
This project will provide nontoxic alternatives to oxidizing biocides for biological fouling control (both micro- and macrofouling), aiming to provide environmental benefits while maintaining or improving facility thermal performance. Plant efficiency will become increasingly important in light of possible carbon dioxide emissions constraints.

Impact
- Provides environmentally acceptable alternatives to chlorine for biofouling control
- Improves or maintains plant heat rates using environmentally acceptable options for controlling biofouling and also possibly reducing corrosion in cooling and service water systems

How to Apply Results
Project findings and deliverables will assist power plant water engineers and scientists in minimizing biofouling where chlorine use is restricted. Operating guidelines will assist water engineers and scientists in managing service and cooling water biofouling while maintaining plant efficiency and reliability. Power plants may participate in pilot- and full-scale evaluations of alternative biocide approaches.
Biotechnological Approaches to Remove Boron from Wastewater (072162)

Background, Objectives, and New Learnings

Boron (B), a common constituent in discharges from coal ash management facilities, is facing increasing regulatory scrutiny. Although typical boron concentrations in these discharges are relatively low—less than 20 mg/L—they may exceed applicable standards. Concentrations as high as 100 mg/L have been observed. Currently, no commercial wastewater treatment technologies are capable of cost-effective boron control, leaving power producers potentially exposed to high compliance costs.

Based in part on work by EPRI in the 1990s, high-volume utility wastewaters containing low concentrations of heavy metals, selenium, and additional contaminants are being successfully treated using constructed wetlands. Bioremediation methods have not as yet been applied for boron removal, but plants and microorganisms capable of growing in and treating water and soil containing extremely high boron concentrations have been identified in recent exploratory research by EPRI. Next steps are to understand and optimize boron uptake capabilities, to conduct laboratory proof-of-concept tests on utility wastewaters, and to initiate field trials.

Project Approach and Summary

This project will support and extend the promising early-stage developmental work funded through EPRI’s Technology Innovation Program. To date, multiple plant and bacteria species capable of tolerating very high concentrations of boron have been discovered. This includes a Turkish grass that survives and grows in soil and water containing more than 1500 ppm of boron—the highest tolerance level reported to date for a plant species—as well as a microbe that thrives at concentrations of 7500 ppm and higher. Additional microorganisms are being isolated from water and soil samples taking from boron-contaminated sites.

Ongoing laboratory experiments are quantifying the practical potential of individual species and exploring growth conditions and genetically mediated pathways for optimizing boron uptake by natural or transgenic plants and microorganisms. Depending on exposure conditions, the EPRI-discovered microbial strain has demonstrated the ability to accumulate from 78 to 1,000 µg boron/g of dry cell—a value one to two orders of magnitude higher than the best previously reported figure for a bacterial species. Genes influencing boron tolerance, uptake, and immobilization have been identified for the Turkish grass and in three other plant species, and analogous work is under way for microbes.

In 2011, laboratory-scale wetlands and a bioreactor will be constructed, incorporating hyper-accumulating plants and microorganisms. Synthetic water will be used to test the ability of the plants and microorganisms to uptake and sequester boron. Proof-of-concept testing on samples of real-world ash management facility wastewater is scheduled to begin in 2012. Field demonstrations would be conducted in a follow-on project once a host sites are identified.

Benefits

EPRI will lead participants in this project to help accelerate development, testing, and optimization of innovative, biotechnology-based treatment systems that promise to meet applicable standards for boron discharges from coal ash management facilities on a year-round basis. The public will benefit from this research through improved water quality and environmental conditions related to elevated boron concentrations in waste streams which could potentially affect water bodies. Participating companies will gain early access to results and have the unique opportunity to supply coal ash wastewater samples from their own facilities for laboratory-scale treatability evaluations.

Participants also will be positioned to host field demonstrations of constructed wetland and bioreactor technologies at sites facing boron compliance issues. In commercial applications, low-maintenance passive treatment systems incorporating boron “hyper-accumulators” are projected to yield significant site-specific savings, relative to the cost of installing and operating existing, conventional wastewater treatment technologies.
Power Plant Wastewater Treatment and Management (071888)

Background, Objectives, and New Learnings

The electric power industry is facing many new federal and state regulations and community pressures that will affect how power plants use and discharge water. These pressures are already impacting the availability and operation of existing plants and permitting of new generating units. Over the next decade, as new control technologies and new fuels (such as biofuels) are deployed to satisfy more-stringent air pollution limits, releases to wastewater and solid waste streams may contain new or greater amounts of contaminants. These changes will require the use of new or enhanced water management and treatment approaches.

Meeting these challenges requires a comprehensive approach to managing power plant water, including initial withdrawal, characterization of wastewaters, treatment options to meet reuse water quality requirements or discharge limits, and ultimate fate in the environment. A key component of this research project is to ensure the availability of a range of control technology options for managing and treating various high- and low-volume discharge streams.

Project Approach and Summary

The project proposes initiation of key research activities focused on wastewater treatment technology development for fossil power plants. Based on industry feedback, the following technology development areas are particularly critical:

- Evaluation of treatment technologies focused on removing mercury and selenium (as well as other pollutants) from FGD and other wastewaters.
- Evaluation of treatment and management approaches for low-volume (non-ash, non-FGD) wastewaters, including recycling and reuse.
- Evaluation of thermal zero-liquid-discharge (ZLD) approaches to evaporating and reusing wastewaters. This research will include the management of solid residues (full ZLD) and brine concentrate (partial ZLD), as well as materials of construction to avoid corrosion.

The specific 2011 work scope will be finalized by the project funders based upon available funding. This research will be coordinated with separate wastewater treatment projects addressing hybrid biofilm reactor and iron coprecipitation for FGD water treatment, hybrid zero-valent iron for removing toxic metals from industrial wastewater, and full-scale vertical flow wetland performance monitoring.

Additional R&D is needed to evaluate novel and promising approaches for water treatment. A literature and vendor survey will be conducted to identify additional promising technologies for review and prioritization by EPRI and the project funders. Promising technologies include

- nanotechnology for selenium and mercury treatment,
- novel activated carbon approaches,
- novel iron-based reagents,
- microfiltration targeting submicron mercury particles, and
- ettringite coprecipitation for boron and selenium.

A secondary function of this project will be to create an interest group forum for participating companies to share information on wastewater discharges and treatment/management approaches. EPRI will organize several meetings or teleconferences during 2011 to provide a forum for these discussions; present the latest data, issues, and findings; and discuss new initiatives.

Benefits

This research project will accelerate characterization of power plant liquid discharges and the ability to reduce pollutant species in these streams to expected or actual regulatory/permit limits. An interest group will be formed as part of this project to help power companies learn from the experiences of others as they address near-term operations of wastewater treatment systems.
Waterpower - Program 58

Program Overview

Program Description
A focus on renewable and noncarbon-emitting energy sources presents new opportunities for waterpower development. There are also opportunities for increased revenue from carbon credits and green energy power sales. Hydropower is challenged, however, by concerns related to fish passage restrictions, turbine mortality on downstream migrating fish, and potential greenhouse gas (GHG) emissions from reservoirs. Through its Waterpower program, the Electric Power Research Institute (EPRI) is uniquely positioned to cost-effectively address these issues and inform technology and policy development.

The Waterpower program assesses the potential, status, generation and environmental performance, and cost of waterpower technologies, including conventional hydropower and emerging ocean, tidal, and in-stream energy technologies. The program supports research on national and international issues of relevance to the waterpower industry, including technology development and optimization, resource assessment, fish passage and protection, environmental impact assessment and stewardship, and waterpower’s relevance in a low-carbon future.

Research Value
This research helps the waterpower industry develop balanced, science-based strategies to optimize performance and safety, protect ecological resources, and allocate water to ensure continued cost-competitive hydropower operation while meeting other stakeholder and public needs. The program supports a public-private collaborative to develop the next generation of “fish-friendly” hydropower turbines. The program provides research and technical results that support recognition of hydropower as a renewable energy resource. Additional program research on emerging opportunities for marine energy technologies (ocean and tidal) allows interested parties to stay current with the latest technology developments while collaborating on innovative concepts for utility marine-energy electric applications and products. Critical motivation for this research is that the hydropower industry

- may lose designation as a renewable energy technology and be ineligible for renewable portfolio standards and reduction/elimination of carbon credits and power premiums,
- may face increased relicensing costs,
- may be precluded from new development (at nonpowered existing dams and new dams), and
- may lose generation (revenues) as a result of stringent fish protection requirements, including high cost for mitigation (fish passage and restoration).

Approach
This program provides information, innovative mitigation technologies, and expertise to help the waterpower industry, government agencies, nongovernmental organizations, and the public effectively plan and manage waterpower development projects while also protecting environmental resources. The program delivers

- technical reports on critical waterpower industry issues, including resource potential, development needs (R&D, economic incentives, and regulatory enhancements), environmental production methods, and operation and maintenance of existing infrastructure;
- technical briefs that provide interim updates on critical industry issues;
- conferences and workshops where waterpower industry issues and opportunities can be explored and discussed; and
- the latest information on fish passage and protection and new ocean energy and hydrokinetic technology.
Accomplishments

There is a newfound enthusiasm for what traditionally is considered a mature technology. Generation-related research focuses on optimizing the performance and value of hydropower as a low-carbon energy resource. Environment-related research focuses on maintaining EPRI's fish passage and protection reference manual and developing the next generation of environmentally enhanced (fish-friendly) hydropower turbines. New research focuses on concern over hydropower's potential contribution to GHG emissions. Program accomplishments include:

- performance assessments and information on upstream and downstream fish passage technologies;
- assessment of waterpower's resource potential and research, development, deployment, and demonstration needs;
- valuation of the services hydropower provides to transmission grids;
- information resource documents on environmental protection, mitigation, and enhancement approaches;
- sound technical information to support federal and state endangered and threatened species listing assessments;
- advancement of fish-friendly turbine technology, including financial support from the U.S. Department of Energy (DOE);
- resource assessments for wave and river hydrokinetic technologies; and
- workshop and conference reports/proceedings on hydropower in a low-carbon future and related new opportunities and challenges.

Current Year Activities

Program R&D for 2012 will focus on continued development of the Alden Research Laboratory, Inc. fish-friendly turbine, information summaries on key operational and maintenance (O&M) and performance optimization issues, and development of new information on hydropower pumped-storage development and opportunities. Specific efforts will include the following:

- Preparation for field deployment, demonstration, and testing of the Alden fish-friendly hydropower turbine
- Technology roundup analysis of key O&M issues, including plant performance optimization and operating strategies
- Assessment of waterpower growth opportunities and the R&D efforts required to attain them
- Interest group activities in the area of hydropower, ocean, river, and tidal energy
- Ocean and hydrokinetic energy resource assessment updates and environmental impact analyses
- Examination of waterpower's role in renewable portfolio standards and carbon dioxide costs or constraints, including periodic intelligence reports, EPRI perspectives, technical updates, presentations, and seminars
- Maintenance and updates of the EPRI Hydropower Fish Passage and Protection Manual
- Development of information on endangered and threatened species of relevance to waterpower operations (such as American eels and sturgeon)

Estimated 2012 Program Funding

$0.75M

Program Manager

Paul Jacobson, pjacobson@epri.com
Summary of Projects

<table>
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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>P58.001</td>
<td>Hydropower Technology</td>
<td>The Hydropower Technology project addresses asset optimization and current industry issues. This collaborative research forum offers seminars and workshops to address current industry topics of interest and provides a roundup report on selected topics.</td>
</tr>
<tr>
<td>P58.002</td>
<td>Fish Passage and Protection</td>
<td>EPRI monitors the technical literature for state-of-the-art information on fish passage and protection at hydropower projects. An annual summary of developments is prepared, and the EPRI web-based fish passage and protection manual is updated as necessary.</td>
</tr>
<tr>
<td>P58.003</td>
<td>Advanced (Fish-Friendly) Hydropower Turbine Design Development</td>
<td>Engineering design; turbine model testing, including engineering and economic performance analysis; and field test plan development will be completed in preparation for future field deployment and demonstration of the advanced fish-friendly hydropower turbine.</td>
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P58.001 Hydropower Technology (063334)

Key Research Question

Many conventional hydropower plants are aging assets and may require increasing demands on performance. At the same time, the value of these plants and their part in electric grid operations is increasing because of hydro's proven flexibility, fast response, and renewable and low-carbon-emitting attributes. Modernization issues include meeting environmental constraints, addressing CO₂ policies, and optimizing operating efficiency while delivering more precise control of plant output for regulation and ancillary services. Accreditation issues relate to qualifying for production tax and renewable energy credits, low-emitting and green power certificates, and other incentives for capacity expansions and efficiency improvements.

Approach

This project addresses current hydro industry issues through collaborative R&D on topics related to hydropower issues and opportunities of interest to members. The project aims to create a forum for members to discuss O&M practices that are of mutual interest. Reporting will depend on participation and the nature of the projects. A summary or roundup report on selected topics is planned. Participant meetings are held in conjunction with hydropower industry events such as the HydroVision, National Hydropower Association, and Waterpower conferences. As larger or more complex issues are identified, this project will address research needs in a collaborative structure, allowing reduced individual member costs and broadening access to technical expertise.

Impact

- Facilitating the exchange of information and sharing of best practices to position hydropower asset owners for a larger role as a non-emitting and renewable generation option
- Creating opportunities for collaborative R&D activities and sharing of experience with new technology applications for improving maintenance and operations in existing facilities and for optimizing plant operations
- Addressing current hydro industry technical issues through industry surveys, case studies, and an ongoing series of roundup summary reports
- Providing opportunities for interactions among peers to identify key issues in today's hydro industry and to pool resources to investigate and develop solutions of mutual benefit
How to Apply Results

This project aims to improve O&M performance and help members revalue assets in existing hydropower facilities relative to new electricity market and system operator demands. The work addresses three application areas that present opportunities for hydropower: optimizing performance of existing assets, recognizing value for hydropower flexibility as other variable generation increases, and qualifying incremental hydropower additions as low-impact and renewable generation.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Hydropower Roundup Report:</strong> This product will be a benchmarking report on how hydropower assets currently operate in today's electricity markets and how future operating requirements and markets might evolve with hydropower as more variable renewables are added to the grid. This product has been combined with hydropower products from ongoing efforts in quantifying the value of hydropower to the electric transmission system. Results of this work include hydro and power system modeling, hydro plant cost elements, hydro in future grid scenarios, and results of hydro plant case studies in different markets. The report in 2012 will include the following: executive summary, value calculation, modeling results, cost benefit and market comparison gaps and recommendations to rules (Independent System Operators), hydrological constraints, operational opportunities, technological opportunities, comparison with the Value Proposition for a Europeans Supergrid, conclusion, and future research.</td>
<td>03/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

P58.002 Fish Passage and Protection (101904)

Key Research Question

Protection of migratory and nonmigratory fish populations is an issue for most hydroelectric projects. Protection and passage requirements are expensive, reduce operating capacity, and limit development of the additional U.S. hydropower generation potential. Relevant information on design and operation of fish passage facilities is scattered, and many designs are untested or in need of further development. In a 2008 EPRI-sponsored workshop to identify the hydropower industry's prioritized R&D needs, fish passage and protection ranked in the top three.

Approach

This project focuses on gathering new fish passage and protection information and maintaining EPRI's web-based fish passage and protection technical reference manual. This reference on technologies and approaches for upstream and downstream fish passage will be revised as required by developments in research and application of technologies. Monitoring of professional literature and publications by resource agencies and Federal Energy Regulatory Commission licensing results will support determination of the need for revised chapters. This project also investigates fish protection issues that are relevant to hydropower operation (such as American eels and sturgeon) and conducts research on development, optimization, and evaluation of fish passage technologies.

Impact

Participation in this project provides the following benefits:

- Assistance and state-of-the-art technical information on all aspects of cost-effective approaches for fish passage and protection
- Contribution to the development of sound life-history technical information on fish and wildlife under consideration for federal and state listing as endangered or threatened species
How to Apply Results

Hydroelectric project owners, operators, and stakeholders will use project information and technologies to analyze and plan environmental protection, mitigation, and enhancement alternatives during relicensing of private investor–owned projects and during National Environmental Policy Act assessments conducted for federal projects.

2012 Products

<table>
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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td>EPRI Hydropower Web Site: EPRI’s website for hydropower resource, licensing, environmental, and fish passage and protection technology information will be updated as needed.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td>Review of New Developments in Fish Passage and Protection: Annual reviews of the technical literature on developments in fish passage and protection will be prepared and distributed to program funders. EPRI’s Fish Passage and Protection manual, a resource on <a href="http://www.epri.com">www.epri.com</a> for state-of-the-art knowledge on fish passage and protection at hydropower projects, will be updated as necessary.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>

P58.003 Advanced (Fish-Friendly) Hydropower Turbine Design Development (067514)

Key Research Question

Development of environmentally enhanced, fish-friendly hydropower turbines that cause minimal injury to passing fish offers an opportunity to maximize energy production while simultaneously providing a safe passage route for fish migrating or moving downstream. Fish-friendly turbines may also lead to development of additional waterpower energy resources, particularly at existing dams without hydroelectric power.

Approach

This project completes the engineering design of the Alden fish-friendly hydropower turbine for installation and testing at a hydropower project. In 2009, EPRI was awarded a two-year, $1.2 million research grant by DOE to complete the preliminary engineering design and model testing of this turbine. With completion of this research in 2011, the turbine will be ready for field deployment and testing. In 2010, EPRI initiated an effort to canvas the hydropower industry for potential demonstration sites for the Alden turbine. A site was selected in 2011. Research in 2011 focused on preparation of the Front End Engineering Design (FEED) for installation and testing of the turbine. Efforts will also focus on finalizing the test plan to assess the turbine’s performance. Work in 2012 will be directed toward deployment and field evaluation of the turbine. Annual workshops for the industry, government, and the public will keep stakeholders informed on research progress and future deployment and field testing developments.

Impact

- Fish passage survival and energy efficiency improvements through selection of optimized turbine system designs
- Advancement of hydropower as a component of renewable energy options

How to Apply Results

The information will be used by hydroelectric project owners and operators in planning new hydropower developments as well as in upgrading existing projects with advanced hydropower turbine systems. Members are encouraged to attend workshops and meetings to obtain the results of the advanced hydropower turbine demonstration and the path for installing the technology.
### 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Evaluation of Fish Survival Through an Advanced Hydropower Turbine System (Fish-Friendly Turbine):</strong> This report will summarize the results of fish survival monitoring after passage through the fish-friendly hydropower turbine. Testing will be conducted at a field site where the advanced turbine is deployed.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
Supplemental Projects

Fish Friendly Turbine Demonstration Project (072034)

Background, Objectives, and New Learnings

Hydropower offers growing opportunities to increase power generation from renewable, carbon-free technologies if several economic and environmental hurdles can be overcome. Addressing these challenges could result in an additional 25,000 MW or more of domestic hydropower capacity. This project will focus industry support for further development and testing of an energy-efficient, environmentally enhanced hydropower turbine.

Increasing worldwide demand for renewable energy and the ability to produce power while minimizing carbon dioxide emissions and other environmental impacts have become driving forces in renewed hydropower development. A new hydropower technology that has the potential to meet power demands without impacting fish is the Alden fish-friendly turbine, which was developed through DOE's former Advanced Hydro Turbine Systems Program and, more recently, with support from EPRI.

The Alden turbine is designed to allow the safe passage of downstream migrating fish, thereby avoiding the need for nongenerating spill over dams or through fish bypasses and minimizing, if not eliminating, the need for expensive downstream fish passage facilities. The Alden turbine can be used to increase generating capacity at existing projects, add generation to nonpowered projects, recover energy that is lost in minimum flow releases, provide generation at new developments, and, where fish passage issues are critical, replace existing turbines that cause unacceptable fish passage mortality.

Project Approach and Summary

EPRI, via a grant from DOE and industry cofunders, has completed the engineering design of the Alden turbine. The collaborative research improved the performance characteristics of the Alden turbine while maintaining its fish-friendly characteristics. The research resulted in the preliminary engineering required to make the turbine commercially available. Design modifications to the turbine components were shown to improve the turbine efficiency to almost 94% at the selected design point, while providing the same or slightly improved fish survival characteristics. The predicted survival rate of fish passing through the full scale turbine is greater than 98% for a 200-mm-long fish. These turbine modifications were also selected to decrease manufacturing and supply costs, resulting in a design that is significantly more competitive than the earlier version. The turbine is now ready for field deployment and testing.

This next collaborative effort will support development of the demonstration project, engineering design to adapt the preliminary design to the head and flow specifications of the demonstration site, and future fish passage survival testing and economic performance evaluation.

Benefits

Hydropower turbine–induced mortality of downstream migrating fish and associated mitigation practices required by regulators generally result in a loss of power output. Successful demonstration of the advanced turbine will minimize mitigation needs and maximize power output. The public may benefit from this research by reducing costs of power generation through association of mitigation practices to reduce fish mortality. In addition, the public may benefit by the potential of improved environmental outcomes associated with this research. In 2004, DOE estimated that as much as 25,000 MW or more of additional power is available at existing dams, and much of this capacity is suitable for an advanced turbine application. In April 2011, the first federally funded hydropower station was launched as part of new efforts to generate 80% of America's electricity from clean energy sources by 2035. Successful demonstration of turbine efficiency and low fish mortality could lead to additional hydro generation, which could exceed the renewable generation provided by all current U.S. wind generation. In addition to improved power output and fish protection, companies may realize credit toward state Renewable Portfolio Standards.
Generation

Making today’s fossil generating fleet cleaner, more efficient, and more reliable, and developing tomorrow’s advanced generation technologies and emissions controls

Advanced Coal Plants, Carbon Capture and Storage
66 CoalFleet for Tomorrow® — Future Coal Generation Options
   66A: Engineering and Economic Evaluations and Market Assessments of Advanced Coal Generation Options
   66B: Gasification-Based Power Plant Development and Deployment Support (IGCC)
   66C: Combustion-Based Power Plant Development and Deployment Support
165 CO₂ Capture and Storage

Combustion Turbines
79 Combustion Turbine (CT) and Combined-Cycle (CC) O&M
80 New Combustion Turbine/Combined-Cycle Plant Design and Technology Selection
88 Heat Recovery Steam Generator (HRSG) Dependability

Environmental Controls
71 Combustion Performance and Emissions Control
73 Post-Combustion NOₓ Control
75 Integrated Environmental Controls
76 Particulate and Opacity Control
77 Continuous Emissions Monitoring
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   178A: Technology-Based Business Planning Information and Services (TAG®)
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   84A: Renewable Energy Economics and Technology Status
   84B: Biomass
   84C: Solar
   84D: Wind
   84E: Geothermal
Program Overview

Program Description

Around the world, electricity is produced largely from fossil fuels, and coal often is the predominant fuel choice. In North America, Australia, and parts of Europe, Asia, and Africa, coal-fired power plants supply more than half of the electricity consumed. However, as public concern over the environmental impacts of coal-based generation increases, new technologies and practices to improve plant efficiency and reduce emissions of air pollutants and greenhouse gases are of interest. If cost-effective, reliable, and highly efficient new coal plant designs with near-zero emissions and CO₂ capture are available to the industry, coal could be kept in the generation mix to constrain expected increases in electricity and natural gas prices.

The Electric Power Research Institute’s (EPRI’s) CoalFleet for Tomorrow® program (Program 66) targets the technical, economic, and institutional challenges to making highly efficient, near-zero-emission coal plants with CO₂ capture a prudent and practical investment option.

Research Value

The program focuses on deploying a portfolio of advanced coal technologies, including integrated gasification combined-cycle (IGCC), ultra-supercritical pulverized coal (USC PC), and oxygen (rather than air) combustion for PC and circulating-fluidized-bed combustion (CFBC) units. The program's R&D:

- Ensures that cost-effective, reliable, and highly efficient new coal plant designs with near-zero emissions and CO₂ capture are available to industry
- Provides timely and accurate engineering and economic information about advanced coal technologies to support generators' decision-making processes
- Serves as a source of accurate, unbiased information on the cost and status of advanced coal power generation technology for policymakers and regulators
- Facilitates implementation of the EPRI-Coal Utilization Research Council (CURC) roadmap for the development of the next generation of coal power, including USC PC that will achieve 47% higher heating value (HHV) thermal efficiency (without CO₂ capture), and IGCCs based on H-class combustion turbines and advanced membranes for O₂ production and CO₂ capture
- Identifies optimal design strategies for integrating CO₂ capture and compression systems with coal power plants—either for greenfield projects or retrofits
- Shortens the development time for promising CO₂ capture technologies (post-, pre-, and oxy-combustion) through the cosponsoring support of the U.S. Department of Energy (DOE’s) National Carbon Capture Center—a “plug-and-play” pilot- and sub-pilot-plant-scale testing facility.

Approach

Working with advanced coal power project owners and developers, power industry equipment and service suppliers, and independent world-class experts, this program develops evaluation tools and technologies to help guide the design of innovative coal plant systems that manage cost and risk. EPRI works with DOE, CURC, and numerous international organizations to include technology and information from public and private sources in coordinating advanced coal research, development, and demonstration.

- Engineering and economic evaluations and market assessments of advanced coal generation options help power generators screen technology options and conduct feasibility studies that assess the economics, operating performance, and technological risks of both gasification- and combustion-based advanced coal generation technologies.
The CoalFleet roadmap for IGCCs sets out a plan for driving down capital cost by 30% by 2025 and, at the same time, improving thermal efficiency with CO₂ capture from today's level of about 30% to almost 40% by 2025.

CoalFleet's UltraGen strategy lays out a plan for improving the thermal efficiency of PCs by increasing steam temperatures in prudent steps to 1400°F (760°C) while implementing improved CO₂ capture and compression. The end point is a design that will achieve almost 40% thermal efficiency by 2025, while creating fewer CO₂ emissions than a natural-gas-fired combined-cycle unit.

Accomplishments
Program deliverables support organizations considering the deployment of advanced coal power generation technology, either now or in the future. For example:

- Engineering and economic information is used by industry to support its coal technology evaluations and generation asset planning.
- Congressional testimony and other outreach activities have provided guidance on technical objectives and levels of research, development, and demonstration funding needed for coal-power CO₂ capture and storage technologies to reach commercial readiness.
- Vital laboratory and in-service test data support qualification of high-temperature boiler and steam turbine materials for USC steam conditions of up to 760ºC (1400ºF).
- CoalFleet has invested more than $3.5 million in the development of its IGCC User Design Basis Specification, the most comprehensive compilation on IGCC state-of-the-art and lessons learned available anywhere. The 1,100-page document covers all aspects of IGCC design including feedstock choice, environmental and safety issues, and designing for reliable operation and maintenance.
- CoalFleet has invested more than $2.5 million in the development of its Guideline for Advanced Pulverized Coal Power Plants. Drawing on EPRI’s wide knowledge base on coal plants, the guideline compiles all the information that a new plant buyer must know before deciding what to build.
- A series of multimillion-dollar engineering studies have provided up-to-date cost and performance information on state-of-the-art IGCC and USC PC designs. Among other conclusions, the studies have shown that increasing PC thermal efficiency by using advanced steam conditions will provide cost-effective (<$25/tonne) reductions in CO₂ emissions, and that judicious use of pre-investment will significantly moderate the cost and efficiency impact of retrofitting CO₂ capture in an IGCC.
- CoalFleet experts have helped several program member companies define the scope of CO₂ capture and storage projects, and assisted them in the preparation of proposals for government-sponsored demonstration projects.

Current Year Activities
The program R&D for 2012 will focus on informing stakeholders about the status of advanced coal power generation technologies and advancing the development of technologies that can provide a significant improvement in the economics of coal power plants with CO₂ capture and storage. Specific efforts will include:

- Updated engineering-economic evaluations and assessments of market trends and commercial technology offerings
- Optimized designs for integrating CO₂ capture and compression processes in both new power plants and retrofits
- Pilot-scale research and test results for pre-combustion and oxy-combustion capture of CO₂ and auxiliary components
- Vital laboratory and in-service test data to support qualification of USC boiler and steam turbine materials
- Implementation of projects identified in the CoalFleet IGCC and PC R&D Roadmaps

Estimated 2012 Program Funding
$4.75M
Summary of Projects

PS66A Engineering and Economic Evaluations and Market Assessments of Advanced Coal Generation Options (062001)

Project Set Description
This project set helps power generators screen technology options and conduct feasibility studies that assess the economics, operating performance, life-cycle greenhouse gas emissions, and technological risks of both gasification- and combustion-based advanced coal generation technologies, and compares them to natural-gas-fired alternatives. In addition, the project set monitors the status of advanced coal power generation technologies and provides information on numbers and types of commercial-scale coal power plants being built in markets of interest to our members.

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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P66.001</td>
<td>Advanced Coal Technologies Knowledge Base; Assessment of Economics, Experience, and Markets</td>
<td>This project helps power generators understand the technical and financial risks of advanced coal investments.</td>
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</table>

P66.001 Advanced Coal Technologies Knowledge Base; Assessment of Economics, Experience, and Markets (062002)

Key Research Question
Electricity suppliers face tremendous challenges to producing affordable electricity, including fluctuating natural gas prices, energy supply concerns, and the need to address climate change. Heightened demand for new coal power generation worldwide (along with high demand for mining equipment, ore-processing facilities, oil refineries, chemical/fertilizer plants, and other capital-intensive industrial facilities) resulted in very large increases in the price of advanced coal technologies that peaked in mid-2008. More recently, the economic downturn appears to have reversed some of the escalating trends; however, in some cases, financing may have become more problematic and costly. Generation planners need up-to-date information to make decisions.

Approach
This project helps power generators understand the technical and financial risks of advanced coal investments. Two annual reports address in-service advanced coal plants and new commercial designs, while an online library of information and links at www.epri.com provide situational (i.e., fuel, location, and timeframe-specific) comparisons of technologies in terms of cost, performance, emissions, and CO2 capture convertibility. CoalFleet arranges site tours featuring advanced coal generation technology developments as a part of two technical workshops during the year.

Impact
- Timely and accurate engineering and economic information on advanced coal technologies
- Impartial assessments of the capabilities of advanced coal technologies
- Up-to-date information on the development status of advanced coal technologies
- Site tours featuring advanced coal generation technology developments
How to Apply Results

The online knowledge base and the annual assessment reports serve as reference documents to support planning for new generation capacity, and as guides for selecting technologies to include in preliminary feasibility studies for new coal generation capacity. Attendance at CoalFleet workshops provides members with an opportunity to visit sites of important advanced coal technology developments and receive previews and summaries of project deliverables. Members can use these workshop materials to fully understand the program results and integrate them in their own planning documents.

In addition, members have year-round access to CoalFleet's technical experts to answer questions about the status, cost, and performance of advanced coal power generation technologies. Through CoalFleet's sponsorship of the DOE National Carbon Capture Center (NCCC) in Wilsonville, Alabama, CO2 capture test results will be made available and interpreted by EPRI's advanced coal technology experts (note that this information will be provided to funders of any of the three CoalFleet project sets).

2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Engineering/Economic Evaluations of Advanced Coal Technologies with Carbon Capture and Storage: This annual update will estimate the capital cost, performance, and levelized cost of electricity for PC, IGCC, CFBC, and NGCC technologies, with and without CO2 capture. Also included are assessments of how variables such as coal type, fuel prices, environmental criteria, tax incentives, and penalties affect technology and fuel selection. In addition, a special focus chapter will be written on a topic based on member feedback. In previous years, these topics have included the impact of retrofitting CO2 capture on a plant that was not previously designed for capture; best practices for controlling construction costs; and power plant capital cost inflation indices. Other topics could include preliminary results from ICO2N Alberta CO2 Purity Project, as well as updates on life-cycle analysis (LCA), operating flexibility, and fuel and power markets. The report also compares EPRI costs with those from DOE/NETL, the Global CCS Institute, International Energy Agency (IEA) Greenhouse Gas Program, and others.</td>
<td>06/30/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Coal Technologies with CO2 Capture – Status, Risks, and Markets 2012: This annual update will include analyses of the latest information from operating USC PC, advanced CFBC, and IGCC plants, and pilot/demo oxy-combustion and post-combustion capture plants; evaluations of the latest designs; and assessments of risks and market opportunities for each technology, including environmental performance and CO2 capture retrofit characteristics. Notable new coal power projects will be profiled.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
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</table>

PS66B Gasification-Based Power Plant Development and Deployment Support (IGCC) (062004)

Project Set Description

The low emissions and water use of integrated gasification combined-cycle (IGCC) technology—together with the already proven ability to capture CO2 from pressurized synthesis gas at scale of a million tons per year or more—make IGCC a technology that cannot be ignored in an era when CO2 emissions are scrutinized. Gasification-based processes also offer options for co-production of power and clean transportation fuels or hydrogen and other chemicals, or even dedicated facilities for producing fuels, fertilizer, or substitute natural gas.

The CoalFleet IGCC R&D Roadmap has shown that there is significant potential for improving the economics of IGCCs with CO2 capture. Consequently, this project set focuses on advancing the development of the technologies in the roadmap. This advancement is accomplished by joining research collaboratives for various
technologies and through support of the DOE’s National Carbon Capture Center for hosting sub-pilot and pilot scale tests of pre-combustion CO₂ capture technologies. In addition, lessons learned from current IGCCs are incorporated in design guidelines for new IGCC plants.

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<tr>
<th>Project Number</th>
<th>Project Title</th>
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<tbody>
<tr>
<td>P66.002</td>
<td>Coal Gasification Technology Status - Annual Update</td>
<td>The annual update provides a concise summary of coal gasification technology written by EPRI’s experts.</td>
</tr>
<tr>
<td>P66.003</td>
<td>Options for Improving Cycling Economics of Gasification-Based Power Plants</td>
<td>This project investigates options for improving load-following capabilities of an IGCC by shifting syngas production to nonpower products during periods of low power demand and by shifting large auxiliary loads such as oxygen-production and CO₂ compression from peak power to low-power demand periods.</td>
</tr>
<tr>
<td>P66.004</td>
<td>Plant Design Guidelines for IGCC</td>
<td>Reduces the risk of deploying a new IGCC by supporting the use of standardized and optimized IGCC designs, which maximize plant reliability and shorten project development cycles.</td>
</tr>
<tr>
<td>P66.005</td>
<td>Advanced IGCC Improvements and Next-Generation Designs with CO₂ Capture</td>
<td>This project identifies optimum IGCC design configurations for near-term plants and fosters longer-term development of IGCC with improved CO₂ capture technologies.</td>
</tr>
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</table>

**P66.002 Coal Gasification Technology Status - Annual Update (062005)**

**Key Research Question**

IGCC technology is evolving rapidly in response to cost concerns, the desire to accommodate low-rank coal, and the need to provide a better transition from conventional operation to CO₂ separation. Several new gasification technologies are being scaled up, and a number of new technologies for improving low-rank coal performance and syngas clean-up economics are under development. Generation planners need information about which technologies are ready for deployment and economically viable.

**Approach**

This project provides technical insight into the status, challenges, and opportunities associated with various gasification technologies and feedstock options, including coal, petroleum residuals, and biomass and wastes via an annual report covering technical developments and operating experience. Quarterly updates on commercial gasification projects in development and new technology developments are made available in Knowledge Base B. The project also includes plant visits arranged through the Gasification User Association (GUA), a related supplemental project.

**Impact**

- Impartial technology assessments written by world-class gasification experts
- Up-to-date information on the status of coal gasification technology development
- Increased confidence in decisions about future plant design, project schedules, and implementation timing

**How to Apply Results**

Project planners and developers can use the information contained in the annual report, as well as insights gained during plant visits and CoalFleet technical meetings and webcasts, to understand opportunities and risks involved in deploying coal gasification technologies. Previous annual reports developed by this project are used as reference documents by EPRI members and are considered to be among the best available source of information on the existing fleet of coal-based IGCC units and other pertinent coal gasification facilities.
2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td>Gasification Technology Status - December 2012: This annual report includes the latest information on the operation of existing IGCC plants, the status of commercial projects in development, and the technology development level of new gasification and gas-processing developments. The primary focus is on coal gasification, but additional chapters are included on the gasification of biomass and wastes, petroleum residuals, and underground coal gasification.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Gasification Technology Status - December 2013: This annual report contains updates on the operating experience and lessons learned at IGCC plants, the status of commercial gasification projects in development, and the technology readiness level of new gasification, gas processing, and power generation innovations (gas turbines, fuel cells).</td>
<td>12/31/13</td>
<td>Technical Update</td>
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P66.003 Options for Improving Cycling Economics of Gasification-Based Power Plants (062006)

Key Research Question

As more renewable generation capacity is added, the need to operate coal power plants in a load-following mode will increase. This project examines ways to enhance the cycling capabilities of an IGCC and to find economic uses of the syngas production capacity for nonpower products during periods of low power demand.

Approach

Options for poly-generation will be examined to determine whether they are amenable to cyclic operation and whether they would be economically attractive. In addition, the project will investigate design changes that would allow an IGCC to quickly supply additional power during peak demand periods (e.g., supplemental firing of the heat recovery steam generator [HRSG]) and enable deeper load reductions without negatively affecting heat rate.

Impact

- Because at least 60% of the investment in an IGCC is in equipment outside of the power generation block, it would improve IGCC economics to not have the syngas production equipment stand idle during periods of low power demand.
- By maintaining syngas production at full capacity, it may be easier to rapidly increase power output when called upon, and the thermal cycling of the syngas production equipment will be minimized.

How to Apply Results

The results from this project, together with previous economic modeling results from project set 66A, will help plant designers make decisions that can maximize operating flexibility of an gasification-based power plant while also supporting decisions on capital investments.
2012 Products

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Options for Improving Cycling Economics of Gasification-Based Power Plants</td>
<td>12/28/12</td>
<td>Technical Update</td>
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</table>

**Options for Improving Cycling Economics of Gasification-Based Power Plants:** Flexibility of operation can be the key to maximizing the economics of IGCC plant operation during times when cycling is necessary. The concepts developed to ensure that IGCC plants can load-follow also may have value for baseload operation when power prices rise and fall with demand throughout each day, and particularly in times where ambient temperatures are very high or very low. The study will focus on operational strategies and their estimated impacts on short-term plant economics. Additionally, the study will attempt to identify strategies that may have short-term value, but could result in long-term added costs by adversely affecting parts life for major plant components.

**P66.004 Plant Design Guidelines for IGCC (062007)**

**Key Research Question**

High capital costs, uncertain reliability, long project schedules, lack of standardization, and unique environmental permitting procedures are obstacles to deploying IGCC technology, which can offer superior environmental performance and could be the lowest-cost generating option for coal plants with CO₂ capture. Improved design guidance will enable program participants to move from using first-of-a-kind designs to designs based on lessons learned from early adopters of the technology.

**Approach**

This project supports the deployment of more reliable and economical IGCCs through the use of reference plant designs. It updates and expands an already world-class design guide for IGCC power plants with and without CO₂ capture. Through www.epri.com, the project also provides a continuously updated online reference library (Knowledge Base B) of design studies, operational and experience-based lessons-learned reports, and current project information. Lessons learned by existing IGCC plants and CoalFleet members developing new IGCC projects are incorporated into design guidelines, so that all members can benefit from the knowledge gained by early movers.

**Impact**

The objective of this project is to reduce the risk of deploying coal-powered IGCC plants by promoting the use of reference designs that meet the requirements of power generation companies. The project provides:

- Online IGCC reference information (Knowledge Base B)
- The IGCC User Design Basis Specification (UDBS), which provides power plant developers with the most detailed design guidance for IGCC plants available
- Pre-design and generic design specification reports, which condense public filing documents and nonproprietary descriptions of new IGCC project designs into user-friendly reports
- Participation in the IGCC Design Guidelines Working Group, which can aid in developing in-house IGCC expertise

**How to Apply Results**

Participants may be able to save millions of dollars in engineering costs and shave several months off a project schedule by adopting existing designs and technologies for their projects, allowing for minor adjustments to meet site-specific requirements. Knowledge Base B provides around-the-clock access to technical reference information on gasification and IGCC power plants. The User Design Basis Specification can be used as a primer on IGCC technology and design tradeoffs, as well as a template for creating an IGCC specification document to which suppliers can submit bids. The pre-design and generic design specifications provide concise
descriptions of IGCC early-deployment project designs and give members important technical information on the design and performance of a specific supplier’s technology.

2012 Products

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<tr>
<td><strong>IGCC User Design Basis Specification, Version 12:</strong> This project provides an update of EPRI’s 2011-program-year version of the UDBS, based on new technology developments and insights from new IGCC deployment projects. The UDBS will contain information on plant size, reliability-availability-maintainability goals, equipment train and sparing recommendations, backup fuel considerations, performance criteria, cost and time-to-build targets, operability requirements (e.g., turndown, ramp rate), emissions limits (steady state and startup/off-spec), plant safety, options for CO₂ capture, plant staffing, and maintenance planning. New areas of focus in Version 12 will depend on feedback from members.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>

**P66.005 Advanced IGCC Improvements and Next-Generation Designs with CO₂ Capture (062009)**

**Key Research Question**

Growing concern about the impact of CO₂ emissions on climate change is increasing the need to develop lower-cost methods for capturing CO₂ from coal-based power plants.

**Approach**

This project evaluates options for improving IGCC performance generally for all coal types, and for integration with water-gas shift reactors for CO₂ capture and hydrogen production. The project will examine various levels of CO₂ capture, from 20% up to practical maximums, to understand the incremental cost of capturing increasing amounts of CO₂. In addition, the project will evaluate emerging design options for plants with CO₂ capture.

A primary focus of this project is a series of engineering-economic studies that examine near-term options for commercial-scale IGCCs. As a starting point, plant configurations defined in the UDBS (P66.004) have been evaluated. These case studies were expanded to look at the impacts of additional coal types and advanced turbine, gasification, and gas clean-up technologies. Additional case studies will be conducted on an as-needed basis.

A second focus of this project is to improve the economics of IGCCs with CO₂ capture through development of new, advanced technologies. The *CoalFleet IGCC RD&D Augmentation Plan* (1013219), issued in 2007, provided a roadmap for improving IGCC reliability, availability, performance, and cost. This project will update the 2007 roadmap as well as foster efforts to bring improvements identified in the augmentation plan to reality.

**Impact**

- Independent engineering-economic evaluations of IGCC design options
- Identification of the potential advantages and risks of new technologies proposed for IGCCs with CO₂ capture
- Lower-cost methods of capturing CO₂ from coal-based power plants
- Increased IGCC operating availability, which will improve IGCC economics
How to Apply Results

Results from the engineering-economic case studies will give members realistic, up-to-date information on the cost and performance of near-term commercial IGCC technology. They also will provide guidance on the most economical design configurations for various operating scenarios. This project will monitor progress in implementing the CoalFleet RD&D Augmentation Plan and provide independent assessments of proposed advances, such as improved instrumentation, controls, and processes that could improve IGCC performance on low-rank coals. EPRI members can use this information to guide R&D investment decisions and anticipate when these enhancements will be commercially available.

2012 Products

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<tr>
<td><strong>Next Generation IGCC Technology Status:</strong> The Next Generation Technology Status report will feature information on R&amp;D progress for advanced technologies that fit into IGCC plant applications. The first level of information that will be provided is high-level technology screening. A second level will require discussions with the technology developers and may include systems analysis for an IGCC plant utilizing the advancement. The third level will be a more detailed due diligence activity, wherein economic analysis will accompany systems analysis and an evaluation of Technology Readiness Level. Information will be provided and reviewed in the context of overall goals for cost and efficiency improvement for IGCC plants.</td>
<td>10/26/12</td>
<td>Technical Update</td>
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Additional components of the report may include evaluations of roadmaps developed by other research organizations such as the DOE and IEA, summaries of technical presentations attended by EPRI staff at workshops and technical conferences, and evaluations of operations and maintenance, reliability, and availability information for plants employing advanced technologies.

PS66C Combustion-Based Power Plant Development and Deployment Support (062010)

Project Set Description

This project set concentrates on a wide range of projects for combustion-based coal power generation, including fundamental work such as qualification of stronger, more corrosion-resistant materials to allow boilers and steam turbines to operate at higher temperatures and raise generating efficiency, innovative technologies for oxy-combustion power plants, and design strategies to facilitate greater load-following and cycling capabilities in new coal power plants. A central element of the project set includes identifying optimal designs for integrating CO₂ capture and compression systems with the power plant either for greenfield or retrofit applications.

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<th>Project Number</th>
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<tr>
<td>P66.006</td>
<td>Design and Materials Development for Post-Ferritic (1200°F–1400°F) Advanced Ultra-Supercritical PC Plants</td>
<td>This project is focused on validating the advanced materials needed for boilers and steam turbines to operate with main steam conditions of up to 1400°F (760°C) and 5000 psi (345 bar).</td>
</tr>
<tr>
<td>P66.007</td>
<td>Evaluation of Oxy-Combustion for Advanced PC and CFBC Plants</td>
<td>This project will assess the development status and economics of oxy-combustion as applied to steam-electric power plants and the role that oxy-combustion is expected to play in reducing CO₂ capture costs.</td>
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### Project Portfolio

#### Project Number

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<th>Project Number</th>
<th>Project Title</th>
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<tr>
<td>P66.008</td>
<td>Analysis of Load-Following Strategies for PCs with CO2 Capture Systems</td>
<td>This project will examine options for improving the load-following capabilities of coal-fired power plants equipped with CO2 capture systems—either PCC or oxy-combustion.</td>
</tr>
<tr>
<td>P66.009</td>
<td>Integration of Post-Combustion CO2 Capture Technologies with Advanced PC and CFBC Plants</td>
<td>Engineering-economic studies to identify cost-saving improvements in commercial-scale applications of PCC technologies.</td>
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</table>

#### P66.006 Design and Materials Development for Post-Ferritic (1200°F–1400°F) Advanced Ultra-Supercritical PC Plants (062011)

**Key Research Question**

Part of the overall strategy for reducing the cost of CO2 capture and storage (CCS) is to increase generating efficiency and lower the CO2 per MWh released from the PC boiler. This approach benefits both post-combustion capture (PCC) and oxy-combustion, and also is applicable to circulating fluidized-bed combustion (CFBC) technology. The maximum steam temperature achievable with ferritic steels is below 1160°F (630°C), limiting efficiency to less than 40 percent HHV for a power plant burning bituminous coal and operating at conditions typical for the United States. It is projected that high-nickel alloys, materials with greater strength and corrosion resistance than ferritic steels, will allow steam temperatures up to 1400°F (760°C) and raise generating efficiency to more than 45 percent (HHV). However, these alloys are more expensive and more difficult to weld than ferritic steels, and to date have not been used in coal-fired power plant applications. For use in these more efficient A-USC PC power plant designs, the materials need to be fully characterized and tested under commercially representative operating conditions.

**Approach**

This DOE-sponsored project (a collaborative of public agencies, research laboratories, and industry) is evaluating high-nickel alloys for use in steam turbines and air- and oxygen-fired boilers. Candidate materials are tested in the laboratory and on operating power plants simulating A-USC operating conditions of up to 1400°F (760°C) and 5000 psi (345 bar). The information developed includes creep strength, resistance to fireside and steamside corrosion (with and without coatings), welding procedures, and fabrication techniques. The initial five-year program for steam turbine materials is completed, and additional work is planned.

A 10-year program to characterize boiler materials is approaching completion, and plans are being made to develop a component test facility to be installed in an operating boiler. This will be a circuit containing evaporative and superheat sections, raising steam at 1400°F (760°C) and 5000 psi (345 bar), and includes turbine and pressure relief valves. The facility will demonstrate the suitability of the materials and fabrication procedures used for commercial application. An Advanced Generation Advisory Panel of power producers will help ensure the test facility fulfills power industry requirements and follows the path towards demonstration and commercialization of the technology. Assessment work carried out in Project 66.009 confirms the economic advantage of CO2 emission reductions offered by A-USC power plants.

Annual progress reports—one on boiler materials and components, and one on steam turbine materials and components—summarize work plan accomplishments and results for tests of fabricated components placed in A-USC-simulated demonstration cells at existing pulverized coal units. These yearly progress reports, which include EPRI’s perspective on the outcomes, will become available to members once DOE has reviewed the results.
Impact

- Results of this project could accelerate acceptance of new A-USC materials by codes and standards organizations, prospective buyers, financiers, and insurers, supporting their introduction into the commercial marketplace.
- By enabling efficiencies greater than 45% (HHV), these advanced materials could allow reductions in fuel consumption and overall emissions—including CO₂—by more than 30%, relative to the current U.S. fleet average for PC power plants.
- Demonstration of advanced materials in a power plant environment significantly reduces the risk of unavailability for initial applications of advanced A-USC PC plants.

How to Apply Results

Members will gain early access to information resulting from this project’s research and will get priority in hosting demonstrations of new designs and materials. Once demonstrated, advanced materials will significantly reduce the capital cost and unavailability risk for new, highly efficient A-USC PC plants.

2012 Products

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<tbody>
<tr>
<td>Technical Progress Report on Boiler Materials Development for A-USC Plants: The project provides an annual boiler material testing progress report, pending DOE’s continued funding of the collaborative.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Technical Progress Report on Turbine Materials Development for A-USC Plants: The project provides an annual steam turbine material testing progress report, pending DOE’s continued funding of the collaborative.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P66.007 Evaluation of Oxy-Combustion for Advanced PC and CFBC Plants (065779)

Key Research Question

Boilers designed to burn coal in a blend of oxygen and recycled flue gas (rich in CO₂), instead of air, offer a third technology platform for separating and concentrating CO₂ and provide an alternative to post-combustion solvent or pre-combustion capture processes. Known as “oxy-combustion,” this approach offers potentially lower costs and lower energy penalties for CO₂ capture at PC and CFBC plants, particularly if emerging low-cost oxygen production technologies reach commercial fruition.

Power plants that employ oxy-coal technology for CCS produce a flue gas rich in CO₂ (80%-90% by volume). When moisture is removed, this raw flue gas may be suitable for storage without further processing. Where the geology or regulations require, relatively straightforward partial condensation CO₂ purification technology can be employed to achieve any required purity. A fortuitous side-benefit of oxy-combustion is a dramatic reduction in the release of conventional pollutants to the ambient atmosphere. There is the very real prospect that, with development of technology supplements to the CO₂ purification unit, emissions of each criteria pollutant (CO, VOC, PM, SO₂, NOₓ, and HAPs) could be less than 100 ton/year. These emissions levels would qualify the plant as a "minor source," greatly simplifying air emissions permitting. This would be a breakthrough for coal-fired power generation.

Approach

This project will advance the understanding of oxy-combustion technologies for PC and CFBC plants by evaluating design studies and pilot plant results, as well as their implications for scale-up to larger demonstrations and commercial units, and of how the technology is deployed in pilot plant and commercial scale oxy-coal power plants worldwide. In particular, EPRI will examine oxy-combustion burner performance, boiler heat transfer characteristics, materials compatibility with the different chemical environment within the...
boiler, the technologies that treat flue gas and purify the product CO₂ for geological storage, and the overall power plant process design/control that most efficiently integrates O₂ production and CO₂ purification technology with power plant processes. The impact of deploying advanced ultra-supercritical steam cycles on oxy-coal plant performance will be assessed. In addition, the project will assess the economics of oxy-combustion and the role that it is expected to play in reducing CO₂ capture costs.

Impact

- Accurate information on the status of oxy-combustion technologies, pilot plant results, technical challenges faced, and prospects for their resolution
- Information about the relative costs and likely commercialization timeframe for oxy-combustion as a CO₂ capture measure for coal-combustion-based power plants

How to Apply Results

Members will have early access to objective information about oxy-combustion technology, pilot test results, and early unit design decisions, allowing them to better evaluate the oxy-fuel combustion option for their specific requirements. In addition to the products listed here, Project Set 66C funders will also receive the National Carbon Capture Center (NCCC) annual report described in Project 66.001. An examination of the economic and technical feasibility of pressurized oxy-combustion systems is part of the NCCC research plan.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering and Economic Evaluation of 1300°F Series Oxy-PC power plant: This report will examine deploying a 1300°F advanced ultra-supercritical steam power cycle in an atmospheric-pressure oxy-coal power plant with CO₂ capture.</td>
<td>09/30/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Update on Oxy-Coal Development Activities Worldwide: This report will chronicle worldwide oxy-coal RD&amp;D activities and assess the readiness of the technologies being developed and prospects for deployment at commercial scale.</td>
<td>06/30/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

P66.008 Analysis of Load-Following Strategies for PCs with CO₂ Capture Systems (062013)

Key Research Question

Increased renewable energy generation capacity on power systems will require coal-fired power plants to operate more frequently in a load-following mode. However, the addition of CO₂ capture systems could hinder a plant's ability to load-follow unless that capability is designed in from the beginning.

Approach

This project will examine options for improving the load-following capabilities of coal-fired power plants equipped with CO₂ capture systems—either post-combustion capture (PCC) or oxy-combustion. Both explicit turndown strategies, as well as auxiliary load-shifting options, such as delayed regeneration of capture solvents and off-peak storage of oxygen for later use, will be investigated. In later years, a dynamic simulator may be developed to allow more detailed analysis of load-following issues.

Impact

- Load-following strategies could make new coal plants a low-cost option for peak power.
- As more renewable generation options are added, having the ability to rapidly change power output of a coal power plant will be essential in maintaining power system reliability.
How to Apply Results

The results from this project, together with the results from the economic modeling in project P66.001, will help coal plant designers make cost-effective decisions on investments needed to accommodate expected load-following scenarios.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
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<th>Product Type</th>
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<tbody>
<tr>
<td>Design Considerations for CO2 capture plants with Load Following Flexibility: This report will provide an update on design options intended to specifically improve power plant flexible operation with CO2 capture. The tradeoff between the improved flexibility gained and the additional costs or performance penalties incurred will be discussed.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

P66.009 Integration of Post-Combustion CO2 Capture Technologies with Advanced PC and CFBC Plants (062015)

Key Research Question

Regulations limiting CO2 emissions from coal-fired power plants are expected in the near future in the United States and many other countries. Although technologies for post-combustion capture of CO2 from flue gases have been applied commercially in the chemical and industrial gas industries at a small scale, none has been applied at the scale needed for a large coal-fired power plant. PCC design studies using the latest amine solvents suggest the energy requirements for solvent regeneration (expected to be provided by steam extracted from the turbine circuit) will be large, reducing plant output by 20% or more. However, considerable research into solvents with lower heats of regeneration, including improved amines and alternatives to amines, is taking place around the world. Energy penalties will be further reduced by effective thermal integration, which will depend on the properties of the solvent selected as well as the characteristics of the power plant. Comprehensive and objective analyses of this rapidly changing field are needed to guide power producers planning to integrate PCC technology with new PC or CFBC units or to retrofit capture technology to existing units.

Approach

This project evaluates various PCC technologies for application with new advanced PC and CFBC units. The project will address both designs for retrofit after initial operation without CO2 capture as well as optimal integration of PCC processes in new units that will capture CO2 upon initial commissioning. Two design integration approaches will be investigated. The most operationally flexible design, with the highest capital cost, will incorporate the ability to turn off the PCC system, allowing for increased power production during periods of peak demand. The least flexible design, with the lowest capital cost, also allows the capture system to be turned off, but the power production remains the same. Initial analyses are based on advanced amines, but alternative solvents and capture technologies will be evaluated as data become available.

Impact

- Provides estimates of how incorporating PCC processes into PC and CFBC plants affects power plant costs, performance, and operation, helping improve plans for coal-fired capacity additions and CO2 management
- Provides information on the modifications necessary to existing power plant components such as steam turbines and feedwater heaters, to achieve optimal heat integration of the power and capture plants
- Provides information to reduce outage rates, constraints on ramping and turndown, and operational and maintenance costs for initial applications of CO2 capture technologies in new PC and CFBC units
How to Apply Results
CoalFleet members can incorporate insights from this project into their generation planning studies, plant feasibility and CO₂ capture readiness studies, and corporate carbon management strategies.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration of Post-Combustion CO₂ Capture Technologies with Advanced PC and CFBC Plants:</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>This report will examine integrating an alternative PCC system (other than the advanced amine previously considered) with an 800-MW 1100°F USC PC plant.</td>
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</tr>
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</table>
Supplemental Projects

Gasification Users Association (GUA) (004388)

Background, Objectives, and New Learnings
The Gasification Users Association (GUA) provides users and potential users of gasification technology a network to exchange non-confidential information on the practice and operation of gasification and its associated technologies, including air separation, gas cooling and clean-up, gas separation, and power generation.

Gasification-based plants can provide for high-efficiency, reliable, and environmentally benign generation of electricity and production of other types of energy and chemicals. EPRI has helped advance development of gasification processes through its RD&D program and continues to help the industry apply the results of the work that it has sponsored, as well as related work.

Project Approach and Summary
The GUA is an international organization that meets twice a year, usually in association with gasification or IGCC plant visits in the United States, Europe, or Asia. The annual meeting usually is held in conjunction with the Gasification Technologies Conference (sponsored by EPRI and the Gasification Technologies Council [GTC]). EPRI staff provides technical and management support for the GUA. EPRI arranges the meetings and agenda in cooperation with the members and provides an overview of the status of the technology, in addition to its applications and economics, at each meeting. An annual report includes comparisons of IGCC to other competing power generation technologies such as ultra-supercritical pulverized coal, fluidized-bed combustion, and natural gas combined cycles, as well as updates on gasification technology development activities and commercial projects.

Benefits
To ensure optimum development, the gasification and related technologies industry needs an avenue to exchange information about utility requirements, safety, training, reliability, and power generation considerations. For more than 20 years, the GUA has helped meet this need and today continues serving as an industry group, complementing the RD&D roles of EPRI, individual organizations, and government.
Supercritical Pulverized Coal Power Plant Interest Group (072041)

Background, Objectives, and New Learnings

In the last ten years, more than 15 gigawatts (GW) of new coal-fired power generation capacity has been brought on-line in the United States, and hundreds of GWs have been added elsewhere in the world. Many, if not a majority, of these new plants are based on supercritical steam conditions and use materials that are relatively new to the industry. These new plants may encounter problems that have not been seen in the previous generations of pulverized coal plants.

This interest group will provide a platform to bring together owners of modern supercritical pulverized coal (SCPC) power plants, as well as owners in the process of building or planning new SCPCs, to discuss issues they are encountering with these plants and to make recommendations that will guide EPRI's future research in this field.

Project Approach and Summary

Members of the interest group will meet twice a year to discuss issues and make recommendations that will guide EPRI's future research in areas related to SCPCs. The agenda for the meeting will be set by EPRI in consultation with the members. Where appropriate, outside speakers as well as EPRI's technical experts will be invited to participate in the meetings. A tour of a modern SCPC, or an SCPC supplier's R&D or manufacturing facility, typically will be included in the agenda.

Benefits

By facilitating an interactive network of organizations with interests in the development and application of SCPCs and related technologies, the SCPC Interest Group will provide early insights into the benefits and challenges of using these technologies. Those insights then will guide EPRI's future research in this area, which, in turn, could lead to more-reliable, lower-cost power generation options for society as whole.
University Advanced Coal Generation Research Fund (072042)

Background, Objectives, and New Learnings

The electric power industry, including its technology supplier base, relies on the world's technical universities to educate and prepare the next generation of its technical staff. But the best and brightest students and professors are often attracted to work in areas other than power generation, in part by the availability of significant research funds for “hot” topics. At the same time, the power industry faces an array of technical challenges that will require new approaches to generating power from coal.

EPRI members can help address both of these issues by contributing to a pool of funds that will support applied research on advanced coal generation technology at key universities around the world. The funded research could lead to breakthroughs in technology for coal power generation, while preparing students for careers in coal power research, development, and application.

Project Approach and Summary

Funds collected for this project will be used to support a variety of research projects related to advanced coal power generation carried out at universities, as well as research conducted by graduate-level university students working as summer interns for EPRI's CoalFleet for Tomorrow® program.

The first funds received will support the British Biomass and Fossil Fuel Research Alliance (BF2RA). This alliance provides funds to support a number of research projects at British universities related to the use of coal and also biomass co-firing. In addition to pooling funds from industrial sponsors, the alliance receives funds from the United Kingdom government, so there will be significant value added to EPRI's contribution. Examples of current projects funded by the alliance include dynamic modeling of a supercritical pulverized coal power plant with CO₂ capture ability; intelligent flame detection incorporating burner condition monitoring and on-line fuel tracking; and biomass torrefaction.

A similar national research program in the United States, funded by a combination of industry and the federal government, is the University Turbine Systems Research (UTSR) program. This project also will become a sponsor of the UTSR program, which supports research projects related to turbines used in integrated gasification combined cycle (IGCC) power plants. As a part of becoming a UTSR sponsor, EPRI will select one graduate student for a summer internship, during which the student will work on a project directed by EPRI's CoalFleet staff.

In addition to supporting these two research collaboratives, the project will fund one or more independent research projects at a university or universities. EPRI's CoalFleet staff will develop a request for proposals (RFP), in consultation with the project sponsors, and will send the RFP to selected universities known to have expertise on the applicable topics. A review committee consisting of technical staff from CoalFleet and the project sponsors will select the best proposals, and one or more proposals will be funded based on the availability of funds.

EPRI staff will compile summaries of the research results from the British Alliance, the UTSR program, EPRI's summer intern project, and the directly-funded university project(s) and provide those to the project sponsors. Webcasts will be conducted during the research to apprise funders of the progress and to give funders an opportunity to provide suggestions on how to address the research challenges.

Benefits

This project will sponsor innovative research on the technical challenges to continued use of coal for power generation. The research potentially could lead to lower-cost options for generating power from coal while decreasing the environmental impacts. Funders can gain timely access to world-class university research in advanced coal power projects. They also will be able to guide and encourage students and professors who have an interest in coal power generation technology. In doing so, they will help prepare the future technical leaders of the electric power industry.
Retrofitting Oxy-Combustion to Coal-Fired Power Plants for CO2 Capture (072043)

Background, Objectives, and New Learnings

Coal-fired power plants in the US alone provide more than 300 GWe of installed generation capacity and supply nearly half the electricity consumed. Capturing CO2 produced by coal combustion could be required in both new-build coal-fired power plants and many coal-fired power plants currently in operation. Retrofits of these existing coal-fired power plants to enable CO2 capture pose significant challenges:

- Limited space for new plant equipment
- Limited heat available for integrating any CO2 capture process with the host power cycle
- Cooling water supply limitations
- Replacement power considerations
- Complicated pipe routings to conform with existing layouts

A separate EPRI project is evaluating retrofits of amine post-combustion capture technologies to selected existing coal-fired power plants. It is prudent to also accurately quantify efficiency and economic penalties associated with retrofitting existing plants with oxy-combustion-based CO2 capture technology. In this project, EPRI will examine the retrofit conversion of specific air-coal fired power plants to oxy-combustion with CO2 capture. Based on the site requirements of an existing power plant design provided by a host participant, the study will highlight the technical and economic issues associated with converting the plant to oxy-combustion and with adding the associated air separation unit (ASU) to produce the oxygen and the CO2 purification unit (CPU) that prepares the flue gas CO2 for transport and geologic storage.

EPRI’s CoalFleet for Tomorrow® program has completed an engineering and economic evaluation of deploying oxy-coal combustion with CO2 capture from a new-build ultra-supercritical power plant. This evaluation and others indicate that oxy-coal/CO2 capture is competitive with pre-combustion and post-combustion CO2 capture for new-build and may have some economic advantages. In addition, the projected lower incremental water use associated with oxy-combustion CO2 capture may recommend it over the alternatives. The knowledge gained from the new-build oxy-coal evaluation will be used to assess the suitability of retrofitting the technology to current plants and determining the resulting impact on performance and costs. Oxy-coal combustion technology is applicable to both pulverized coal and fluidizedbed combustion systems.

Project Approach and Summary

Host utility funders will nominate a plant currently in service for this study. A design for retrofitting each nominated plant with oxy-coal combustion and CO2 capture will be established. Modeling work will establish the heat and material balances for the retrofitted plant, size the key components of the ASU and CPU, and determine their auxiliary power requirements. The design will optimize integration of the available heat sources in the air separation plant (ASP) and CPU. All modifications necessary to the plant steam cycle, air quality control system (AQCS), and balance of plant will be addressed.

Benefits

The performance/cost data developed by this project will inform policymakers and generation planners seeking ways to reduce CO2 emissions in the electricity supply sector at minimum cost. The assessments will characterize the suitability of oxy-coal as a CO2 capture retrofit technology and allow comparisons with other CO2 reduction options. It also will identify the unique characteristics of existing power plants that recommend them or make them unsuitable for oxy-coal/CO2 retrofit.

An additional benefit of the work proposed is quantification of the extent to which near-zero emission of criteria pollutants might be achieved using the unique flue-gashandling technologies associated with oxy-coal combustion.
Repowering Coal Power Plants to Retain Capacity and Capture CO2 (072044)

Background, Objectives, and New Learnings

Based on recent analysis by EPRI, coal-fired steam-electric plants with an aggregate capacity of 27,000 MWe or more are expected to be retired in the 2012-2020 period. These retirements are accelerating as the costs of retrofitting control technologies to the boiler/air quality control system to meet tighter emission limits make the plants uneconomical. However, the balance-of-plant equipment at these brownfield sites (steam turbine-generator, cooling water system, electrical system, switchyard, coal storage/handling, ash storage/handling, and infrastructure) may retain significant value when assessing the economics of repowering the site.

This project will assess the feasibility of one or more repowering schemes in specific plants, nominated by project participants, which are being retired or scheduled to be retired. The assessment will use baseline costs and performance previously published by EPRI for new, greenfield, state-of-the art, coal-fired power plants as a comparison.

Project Approach and Summary

The candidate repowering schemes, from which one will be chosen, include:

1. IGCC/PCC: Installation of a combustion turbine/HRSG that uses the existing steam turbo-generator as the bottoming cycle. The combustion turbine is fueled by a new coal-gas plant with heat recovery to the steam cycle (pre-combustion CO2 capture as an option).
2. USC/PCC: Installation of an air-fired ultra-supercritical steam generator with topping USC steam turbine that exhausts steam at the inlet conditions of the existing high-pressure (HP) turbine (post-combustion CO2 capture as an option).
3. Oxy-PC: Installation of an oxy-fired ultra-supercritical steam generator with topping USC steam turbine that exhausts steam at the inlet conditions of the existing HP turbine (CO2 capture included).

All candidate repowering schemes may include power cycle improvements, which would increase capacity and efficiency when CO2 capture is not required, and mitigate any capacity/efficiency penalty when CO2 capture is required. (Coal-use in the respective repowering scenarios is not expected to exceed the site’s original coal feed rate, despite the increasing capacity due to the concurrent efficiency improvements.) Host utilities will specify the extent to which transmission capacity serving the plant will constrain net capacity increase of the repowering. If the host considers that existing turbine cannot be utilized as proposed, then a new turbine will be used for the study.

The greenfield baselines to which these schemes will be compared include:
- A full-scale IGCC with optional pre-combustion CO2 capture.
- A full-scale air-fired USC with optional post-combustion capture.
- A full-scale oxy-coal USC plant with CO2 capture.

Candidate power plants, retired or slated for retirement, will be nominated by project participants. Plants with multiple retired units, which might offer a variety of arrangement options, will also be suitable nominees.

The balance-of-plant assets at the candidate power plants will be screened for remaining service life or costs to extend service life or incrementally improve capacity. Available space for repowering equipment will be identified in cooperation with host utility staff, including whether demolishing the existing boiler/air quality control systems to make space available is advisable or cost-effective.

Preliminary repowering plant designs will be prepared for one of the three scenarios under consideration, selected by the plant owner, in sufficient detail to estimate repowered plant performance and capital/operating costs. EPRI TAG® Class I capital cost estimates will be developed for repowering the nominated plants with the three candidate schemes, along with projections of repowered plant performance and levelized cost of electricity (LCOE). The LCOE for the repowered plants will be compared with LCOE for the full-scale greenfield plants previously developed by EPRI.
Benefits

The results of this project can be used by owners of coal-fired power plants slated for retirement to compare the scope and value of repowering the plants — increasing capacity and efficiency — to construction of greenfield power plants to meet new capacity requirements. The project studies will provide guidance for similar repowering assessments at other plants, retired or scheduled for retirement.
Program Overview

Program Description

Policy watchers and power system planners continue to expect that post-combustion capture will be needed in the 2020 decade for both existing and new coal-fired plants, and somewhat later for gas-fired systems, in order to meet carbon dioxide (CO2) reduction targets being discussed in the United States, by many other governments, and within the United Nations. An associated need for all fossil-fueled electricity generation sources is permanent and environmentally safe storage of the captured CO2. For pulverized coal (PC) plants to provide competitively priced electricity while addressing these CO2 reduction concerns, they need capture processes with much lower parasitic plant loads and costs than systems available today. All power generation sources of CO2 also will need the ability to store large quantities of CO2 safely and permanently in underground formations. While establishing the necessary legal and regulatory framework is not within the purview of EPRI, providing sound technical evidence that storage can be done in a safe and permanent fashion can support the development by others of workable regulations and enabling laws.

EPRI’s CO2 Capture and Storage program (Program 165) provides information about the expected cost, availability, performance, and technical challenges of a range of flue gas CO2 capture processes. The program seeks and encourages the development of breakthrough post-combustion CO2 capture technologies with substantially lower energy and cost penalties. In addition, the program determines purity requirements for the CO2 stream discharged by the capture process to ensure compatibility with the compression, transport, and injection processes, and conducts the R&D needed to demonstrate the permanence, safety, and environmental acceptability of long-term CO2 storage from any power plant source.

Research Value

Substantial barriers must be overcome, and technical and societal uncertainties must be resolved before carbon capture and storage (CCS) can be widely deployed, but time is growing short if a 2020-2025 date for federal CO2 limits materializes. Proposed PC plants already have been denied permits in the absence of firm plans to capture and store their CO2 emissions. This program meets the industry’s most urgent near-term needs—information for:

- Credible asset planning through early understanding of the options, development timelines, costs, technical uncertainties, and regulatory, environmental, and related issues
- Increased confidence that acceptable capture technologies and storage options will be available when needed
- Use in public dialogue on the practical extent and timing of CO2 reduction from U.S. power plants, using neutral third-party data and assessments from EPRI.

Longer-term, the technology development aspects of this program will enable the power sector to continue to provide affordable electricity to industry, businesses, and residences using fossil-fuel-fired generating assets in a low-carbon world.

Approach

This program pursues parallel, complementary activities in post-combustion CO2 capture and in storage of CO2 from any fossil-fueled electricity generation source. For post-combustion capture, EPRI will continue to seek potential breakthrough technologies that offer the promise of significant cost and energy demand reductions over today’s leading candidates. EPRI then will conduct technical and economic assessments of these processes, followed by development and demonstration of the most promising ones, in order to accelerate the availability of commercially mature, cost-acceptable carbon capture methods. Based on offers to collaborate with developers of a number of interesting CO2 capture processes in their bids to the U.S. Department of Energy (DOE) for funding, EPRI may engage in 5 to 10 such activities in 2012 and beyond. For CO2 storage, EPRI will conduct or participate in multiple, large, multiyear CO2 geologic storage projects designed to provide the
information and tools needed to gain public and regulatory acceptance of commercial-scale CO₂ storage. Topical studies (e.g., predicting and countering any environmental impacts of contact between injected CO₂ and potable aquifers) will address other underlying geochemical processes that affect formation and well integrity not tested in the demonstrations. Members receive this information through four projects:

- "CO₂ Capture and Storage Technology Watch" highlights developments and trends in carbon capture and storage through periodic updates on worldwide post-combustion CO₂ capture and storage research. Information is obtained through participation in various international forums, workshops, and conferences.
- "Post Combustion CO₂ Capture Development and Demonstration" conducts assessments of "add-on" CO₂ capture or fixation systems for new and retrofit combustion-based fossil power plants; information on these processes continues to be collected in a database of CO₂ capture processes, with in-depth assessments where appropriate. Increasingly, EPRI's R&D is focusing on collaborations with process developers across the spectrum of technologies to accelerate the development of their concepts. In support of both the assessment and development efforts, EPRI conducts process simulations for further improvements through optimized design and thermal integration with the power plant. Complementing these development efforts, the program continues to co-produce economic studies of diverse post-combustion CO₂ capture technologies and energy integration schemes with the CoalFleet for Tomorrow® Program (EPRI Program 66).
- "Assessments of CO₂ Storage Challenges" summarize experiences in large-scale storage demonstrations; seeks optimum methods and economics for evaluating potential geologic storage formations; quantifies potential environmental risks — e.g., from migration of injected CO₂ into underground sources of drinking water (USDW); considers ways to remediate potential breaches of storage integrity; and assesses the effectiveness of techniques being developed for predicting and monitoring the location of the underground CO₂ plume.
- "Integration Issues – Compression, Transport, and Storage" covers R&D involving CO₂ compression technology and transportation systems. Current efforts focus on the purity of the capture system’s CO₂ product stream needed to ensure long compressor and pipeline lifetimes; the fluid properties of the expected CO₂/impurity mixes needed to develop optimum designs for compressors, piping, valves, and other components; and the ability of the compression system to remove species that could be detrimental to the downstream transport pipelines. In addition, these studies include economic trade-offs between producing low-impurity CO₂ and protecting downstream equipment. CO₂ purity requirements for storage assess the potential geochemical reactions between different levels of impurities (especially SOₓ) in the CO₂ stream and the geologic formation into which the CO₂ is being injected. Research will consider the plugging/dissolution and consequent reduction/increase in injectivity and capacity that could be caused by such reactions.

Accomplishments

EPRI is recognized as a key source of technical information on emerging CO₂ capture processes (including post-combustion processes), as well as the feasibility and issues associated with CO₂ transport and geo-storage. Recent R&D highlights include:

- Managing and completing the pilot-scale (1.7 MWe) testing of the chilled ammonia process, leading to its scale-up by a factor of 10 (to 20-MWe) for the Product Validation Facility program being conducted with EPRI support by American Electric Power (AEP) and Alstom at AEP’s Mountaineer station.
- Identifying and evaluating the technical feasibility of more than 100 novel CO₂/flue gas separation concepts or processes under development, narrowing the promising processes to fewer than 20. Updating earlier assessments to account for recent developments and adding new processes as identified. Providing capsule information and assessments to program members in a web-based database.
- Participating in bids to DOE for further development support by approximately half the developers considered most promising by EPRI, thereby giving EPRI members a window into early development status and potential of a wide range of possible CO₂ capture processes — solvent, sorbent, membrane, and mineralization.
• Providing sorbent process developers with feedback on their test approaches, leading to more technically solid progress towards identification of processing sorbents and sorbent-handling systems.
• Completing a scoping test on the potential for CO₂ to alter groundwater chemistry if it migrates from its injection formation into an underground source of drinking water (USDW).
• Identifying and assessing compression options for CCS applications, including new, less energy-intensive compressor designs.
• Informing members about CCS developments worldwide through participation in several international networks of specialists.
• Documenting the process of finding, validating, and permitting injection sites through a management role in two DOE Regional Carbon Sequestration Partnerships and a supporting role in a third partnership.
• Documenting public acceptance, permitting, and legal state-of-the-issue.

Current Year Activities
Program R&D for 2012 will focus on completing efforts already under way — aggressively seeking new capture process ideas from universities and individual developers; actively supporting selected CO₂ separation process developers with system modeling and power plant insights as they advance their technologies under DOE or state funding; investigating potential emissions of solvent or sorbent slip and degradation products; and determining the potential impacts of CO₂ leakage on USDW chemistry (in a more realistic environment than earlier tests). The program also will begin to address the question of CO₂ purity requirements for long-lasting compressors and favorable/safe injection reservoir conditions. Expected products include:

• Findings reported internationally of new technologies and scientific concepts with the promise of significant reductions in the cost and energy requirements for CO₂ capture, and ways to ensure the permanence and environmental safety of geostorage through participation in worldwide networks and conferences.
• Technical and economic assessments of new or improved emerging post-combustion CO₂ capture processes, including select process simulations.
• Progress reports on pilot-scale testing of processes with EPRI involvement that are selected for funding in 2011 by DOE and state agencies.
• Performance reports on the first post-combustion CO₂ capture processes to be tested at the National Carbon Capture Center (expected to be both solvent and sorbent processes, possibly including technologies from abroad and new entries by major U.S. OEMs to the power industry).
• Preliminary concepts for reducing/avoiding atmospheric releases of solvent or sorbent degradation products with the flue gas (pending the finding of such releases in 2010 or early 2011).
• Development of equations of state (EOS) needed to predict properties of CO₂ with impurities to aid in the design of compression, transport, and storage systems
• Preliminary measurements of any changes in potable water quality if injected CO₂ migrates into an underground source of drinking water.
• Initial assessment of the potential impact, if any, of impurities in the CO₂ product stream on the receptivity of target geo-storage formations to receiving and storing large volumes of CO₂.
• Search for concepts for reducing the costs of qualifying geostorage formations.

Estimated 2012 Program Funding
$3.0M

Program Manager
Richard Rhudy, 650-855-2421, rrhudy@epri.com
## Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P165.001</td>
<td>CO2 Capture and Storage Technology Watch</td>
<td>By engaging with other major CO₂ capture research organizations, EPRI provides members with up-to-date information on activities, advances, and findings worldwide.</td>
</tr>
<tr>
<td>P165.002</td>
<td>Postcombustion CO₂ Capture Development and Demonstration</td>
<td>This project investigates post-combustion CO₂ capture processes that are significantly less costly/energy-demanding, produce a solid capable of being landfilled, or minimize water consumption and possible contamination.</td>
</tr>
<tr>
<td>P165.003</td>
<td>Assessments of CO₂ Storage Challenges</td>
<td>EPRI will help develop the information needed to demonstrate that injection and storage of CO₂ into underground formations can be permanent, environmentally acceptable, and safe.</td>
</tr>
<tr>
<td>P165.004</td>
<td>Integration Issues – Compression, Transport, and Storage</td>
<td>This project supports development of materials, systems, and processes needed to economically compress and transport captured CO₂ to storage and use sites. In addition, this project will evaluate the effect that CO₂ impurities produced by the CO₂ capture process will have on the integrity and performance of typical storage formations and the environment, leading to development of better CO₂ purity requirements.</td>
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### P165.001 CO2 Capture and Storage Technology Watch (072085)

#### Key Research Question

Post-combustion CO₂ capture from fossil-fueled electricity generation sources and CO₂ storage from any source (aka carbon capture and storage, or CCS) pose very complex and costly challenges with substantial uncertainty. RD&D to find economically and environmentally acceptable solutions is expensive, but because the impact of CO₂ emissions on global climate is of concern to many nations and nongovernmental organizations, researchers worldwide are seeking solutions. To maximize the value of their RD&D investment, avoid unnecessary duplication, and benefit from the world’s best expertise, members need access to this research.

#### Approach

EPRI will continue to provide a link to the worldwide CCS RD&D community through its participation in several organizations — the International Energy Agency (IEA) Greenhouse Gas Program, Massachusetts’s Institute of Technology (MIT) Carbon Sequestration Initiative, and the British Biomass & Fossil Fuel Research Alliance — as well as staff attendance at numerous conferences and workshops. EPRI provides updates to the advisory meetings and, as appropriate, a newsletter that summarizes the latest findings and R&D directions on post-combustion CO₂ capture and storage reported at these venues. EPRI also informs the research community about power generators’ operability issues, helping guide research.

#### Impact

This project serves as a central information source on worldwide activities and trends in post-combustion CO₂ capture and storage. It provides members a:

- Basis for credible asset planning through early understanding of the options, development timelines, costs, uncertainties, and regulatory issues.
- Dialog about the practical extent and timing of reducing CO₂ emissions from U.S. power plants.
How to Apply Results

Environmental compliance specialists and strategic planners can stay abreast of the latest issues and progress in post-combustion CO₂ capture and storage through advisor meetings, webcasts, newsletters, and contact with EPRI staff. They can use this information to support planning exercises and communications with policymakers, shareholders, the media, and the public.

2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Newsletters on Developments in Post-Combustion CO₂ Capture:</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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<tr>
<td>Ongoing activity, with newsletters or special briefings/webcasts provided one to two times per year as determined by the availability of significant new information.</td>
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Future Year Products

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P165.002 Postcombustion CO₂ Capture Development and Demonstration (062057)

Key Research Question

Commercial post-combustion CO₂ capture technologies used in nonpower applications, if used on power plants, would impose a severe energy penalty on the plant — potentially, more than 30% of plant output for the capture process and compression of the concentrated CO₂ product stream to supercritical conditions. In addition, these processes are very large and complex, resulting in high capital costs and large space requirements. Processes under development (e.g., ammonia-based, advanced amines, solid sorbents, membranes) might require much less plant energy, but it still is too early to guarantee their ability to achieve energy/cost targets that would keep pulverized coal-fired electricity generation units competitive with gas-fired systems in a low-carbon scenario. Therefore, efforts to find and demonstrate processes that could substantially lower costs and energy penalties must continue. At the same time, the industry needs options that fix CO₂ via biological or chemical means as alternatives for cases in which geostorage is not allowed or impractical. In either case, related needs include minimizing water consumption and ensuring that solvent or sorbent residues or degradation products are not released into the environment. And all these challenges must be overcome rapidly so that the power industry will be able to procure and operate the most viable of these systems in time to meet regulatory requirements.

Approach

EPRI will continue to participate in the development of several post-combustion processes that hold the promise of significantly reduced energy/cost penalties, including:

- A membrane incorporated into a novel system design
- Solid sorbents (organic carbon-based, amine-impregnated, and, potentially others found during the ongoing search), along with the demonstration of a modern material-handling systems for the large sorbent volumes that will be required for CO₂ capture
- An advanced solvent, combined with process improvements, to reduce energy requirements.
Starting in mid-to-late 2011, EPRI expects to join with the DOE and potentially other government agencies to help accelerate the development of a number of additional, promising CO₂ capture processes utilizing higher-capacity amines. Some of these processes will be tested at the DOE’s National Carbon Capture Center (NCCC), operated by the Southern Company at Alabama Power’s Plant Gaston, with this program providing a portion of the required private sector cost-share (ensuring widespread industry input into the program). Processes will be chosen for NCCC evaluation on the basis of readiness to move out of the laboratory for testing on flue gas at 0.1-1.0 MWe scale; the goal is to accelerate their advance to a 20+MW field test (at another site). Further, the expertise developed by EPRI under this project also informs the 20- to 25-MW chilled ammonia and advanced amine EPRI Industry Technology Demonstrations at AEP and Southern Company, respectively, with feedback provided to Program 165 members.

EPRI will continue to seek and evaluate novel technologies, supporting any that appear to offer significant advantages such as lower parasitic load, lower cost, or the production of a solid product to avoid the uncertainties of CO₂ storage. This outreach will include major international equipment and chemical suppliers to the power industry, some in alliances with large architect/engineering firms that announced entries into this area in 2010-2011 and can be expected to offer pilot-scale advanced options by 2012. Water consumption will be one of the evaluation criteria, with a search for zero- or near-zero water consumption processes a growing priority. This support may consist of seed funding or co-funding, proof-of-concept tests, process simulations to help inventors move their invention from concept to practical system, or detailed process analyses aimed at improving a process's predicted performance. As new processes are found and information on them becomes available, EPRI will post them on the program’s website in a database with downloading and searching flexibility. If promising new early-stage processes are found, EPRI will conduct proof-of-concept tests.

Impact

Participants in this project receive ongoing, updated information on the progress of EPRI's identification, evaluation, and demonstration of new post-combustion CO₂ capture processes that can deliver one or more of the following benefits:

- Reduced cost-of-electricity (COE) increases due to post-combustion carbon capture from the current estimate of 60–80%, down to levels that are competitive with natural gas-fired electricity generation.
- Reduced parasitic energy demand from approximately 30% to less than 20% (excluding compression).
- Capture and storage of CO₂ as a solid.

Participants also will receive early indications of any releases from the capture process of its capture materials or their degradation products into the environment, and means to mitigate any such harmful releases.

How to Apply Results

Environmental compliance specialists and strategic planners can stay abreast of the latest progress in CO₂ capture technologies by attending advisory meetings, participating in webcasts, and viewing and searching the web-based technology review. They also can follow up with EPRI staff. Members can use this information, backed by firsthand knowledge of promising developments, to support planning and communications with policymakers, the media, and the public.

2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td>Emerging Post-Combustion CO₂ Capture Processes: Web-hosted database compilation of all known post-combustion CO₂ capture processes with descriptions, developers, status, actual or expected performance and cost, and assessment of feasibility and performance/cost projections. Updated periodically, as warranted.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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</tbody>
</table>
### Accelerated Development of Promising Post-Combustion CO₂ Capture Processes

**Planned Completion Date**: 12/31/12
**Product Type**: Technical Update

**Product Title & Description**: Technical update on all emerging post-combustion CO₂ capture process developments in which EPRI is involved. Will include results for projects expected to be selected by DOE for award by mid-2011 as well as the first set of technologies tested at the NCCC, the basis for their selection, and the next set of processes to be tested.

### Environmental Releases from Post-Combustion CO₂ Capture Processes

**Planned Completion Date**: 12/31/12
**Product Type**: Technical Update

**Product Title & Description**: Measurements of solvent slip or solvent/sorbent/membrane degradation products into the environment (mainly air, but also water and solids). Depends on agreement of host sites and process developers to EPRI conducting and reporting these measurements. May be from laboratory- or pilot-scale facilities. This is a follow-up from the literature review completed in 2010.

### Simplified Post-combustion Economics Model

**Planned Completion Date**: 12/31/12
**Product Type**: Software

**Product Title & Description**: Depends on 2011 findings that: a) a need exists for such a model to help developers and potential supporters evaluate the probable costs of new processes at an early developmental stage, and b) no such model exists that is suitable. The resulting model, whether existing or developed, will be designed to enable a new practitioner to use it with no more than one-day setup time to produce a ± 30% cost estimate.

### Future Year Products

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<tr>
<td><strong>Proof-of-Concept Tests of CO₂ Ideal Separation Media</strong>: Laboratory and pilot tests of designer solvents, sorbents, or membranes based on design-to-properties results.</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Accelerated Development of Promising Post-Combustion CO₂ Capture Processes</strong>: Annual update on testing of emerging post-combustion CO₂ capture technologies at NCCC and other sites. Includes tests from laboratory development efforts on early-stage technologies to 0.5-2 MWe equivalent pilots.</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Accelerated Development of Promising Post-Combustion CO₂ Capture Processes</strong>: Annual update on testing of emerging post-combustion CO₂ capture technologies. Includes tests from laboratory development efforts on early-stage technologies to 0.5-2 MWe equivalent pilots.</td>
<td>12/31/14</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Proof-of-Concept Tests of CO₂ Ideal Separation Media</strong>: Follow-up laboratory and pilot tests of designer solvents, sorbents, or membranes based on design-to-properties results. Larger scale or new materials since 2013 report.</td>
<td>12/31/15</td>
<td>Technical Report</td>
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### P165.003 Assessments of CO₂ Storage Challenges (052326)

**Key Research Question**

Although as much as 80% of the cost of CCS is attributable to the capture process, most of the uncertainties surround the means of permanently storing CO₂. The industry and public need confidence in the ability to safely inject and store CO₂ in underground formations over very long periods and with no undesirable side effects. The industry also needs to understand the socio-political issues associated with CO₂ storage, such as legal or regulatory procedures for dealing with long-term liability for injected CO₂, effective methods of communicating...
the measures being taken by the industry to mitigate risks, and successful approaches to permitting underground storage.

Of the wide range of R&D needed to resolve these issues, EPRI is focusing on those that are critical to the industry and yet not being covered adequately by others, and of a scope and content such that EPRI can make an impact directly or through leveraging by participation in a consortium. These efforts are demonstrating the ability to monitor the fate and location of injected CO₂ in underground formations, to ensure its permanence in the target storage formation and absence of intrusion into potable groundwater reservoirs; advancing the understanding of the potential impact of any CO₂ leaks into such drinking water sources; and proving ways to identify and mitigate such leaks if they occur. Research also will seek lower-cost methods to assess reservoirs and develop costs for the full transport, storage, and monitoring set of activities for different source-sink locations and geologic formation properties.

**Approach**

Through its own studies, its participation in several DOE Regional Carbon Sequestration Partnerships, and its participation in the oil-company-led Carbon Capture Project Phase 3 (CCP3), EPRI is supporting efforts to address the need to prove the effectiveness, permanence, and safety of geologic storage of CO₂. These efforts include:

- Experimental and modeling investigations to address questions about the potential for injected CO₂ to render potable groundwater undrinkable if the CO₂ and the impurities that it may contain migrate into such a drinking water source
- Investigation into remediation techniques that could be used in case of CO₂ release from the intended storage formation through wells
- Improving methods of assessing and selecting storage locations
- Developing a better understanding of the reservoir processes during CO₂ injection
- Developing innovative and less expensive approaches for monitoring CO₂ underground

Studies on allowable impurities in the CO₂ stream to avoid deterioration of the injection formation are addressed in Project P165.004.

**Impact**

The project will advance the acceptability of CCS or identify issues that must be addressed to reach this goal. This RD&D will help:

- Increase the knowledge base that will enable CO₂ underground storage (i.e., that industry and regulators will have the necessary experience and tools to engineer and permit such projects) and be understood by government bodies and the public when needed (e.g., 2020 or sooner).
- Provide independent information that can be used by project applicants and policymakers or permit writers to develop workable and scientifically-based regulations and legal frameworks for underground CO₂ storage, guidelines on characterizing a formation before injection to satisfy permit writers and power company risk managers, and technologies to monitor the underground migration of injected CO₂. Achievement of these goals before power companies need to apply for permits can save applicants several years and up to millions of dollars in permitting costs at each of the first several sites.
- Avoid the need to purchase allowances by being able to show permitting authorities that proposed geologic storage is permanent and safe. At a conservatively low allowance price of $20/ton CO₂, this achievement could save a 2,000-MW plant $500 million in purchased allowances over five years if the company does not receive an injection permit.

**How to Apply Results**

Power company personnel at all levels (planning, asset management, environmental engineering, environmental policy, risk management, legal) and management can use the results of this project to assess their options and guide the implementation of their strategies.
2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>CO2 Sequestration -- CCP3 project update:</strong> Update of 2011 status report on CCP3 project efforts to develop a model of CO2 leakage through wells, develop lower-cost monitoring, reservoir processes, and lowering risk of storage sites.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Evaluation of potential CO2 impact on drinking water:</strong> Progress update on project to evaluate the impact of CO2 on a drinking water reservoir through injection of CO2 into a shallow drinking water reservoir and monitoring of the impacts.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<tbody>
<tr>
<td><strong>CO2 Sequestration -- Progress Report on Challenges and Resolutions:</strong> Status Update: Summary/synthesis of lessons learned at injection demonstration sites, the status of the Underground Injection Control (UIC) regulations, approaches being used internationally and in the U.S. states that have adopted geologic storage regulations or legislation, as well as findings from the various EPRI, DOE, and CCP3 studies included in preceding annual reports.</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Site Selection and Permit Applications -- Lessons Learned:</strong> Summary and synthesis of successful practices for obtaining drilling and injection permits. Assessment of tools available to: a) characterize potential storage formations most economically and with highest probability of a positive outcome, b) demonstrate knowledge of location of injected CO2 including potential leaks, and c) identify and mitigate potential risks to potable groundwater (understand the risk and have plan/technologies to remediate, if needed).</td>
<td>12/31/15</td>
<td>Technical Report</td>
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P165.004 Integration Issues – Compression, Transport, and Storage (072086)

Key Research Question

The “chain of CO2” — as it is captured, compressed, transported, and stored — contains many potential challenges. One of the more important is the level of clean-up required in the capture plant to prevent issues in the following “chain links” from compression to storage. Scale, energy requirements, and materials compatibility with potential impurities in CO2 streams are significant challenges facing the industry and its equipment and service suppliers involved in compressing and transporting captured CO2 to storage or use sites. Both flow volumes and energy requirements for CCS systems will be much greater than current industry practice. Cleaning the CO2 stream produced by the capture system to very high purity levels may be expensive, so it is important to determine the impact of impurities on the properties that affect the design of compressors, intercoolers/heat exchangers, and valves, as well as the tolerance of a range of possible compressor and pipeline materials to different levels of impurities.

For storage, limited data are publicly available on potential fluid/formation interactions when the injected fluid is supercritical CO2 derived from a coal power plant. Because this CO2 may contain impurities, information is needed to determine their potential impacts in order to develop reasonable, science-based purity requirements that should be placed on a CO2 stream to allow successful and environmentally safe injection into underground formations. Injected fluids can react with the formation water to produce precipitates, mineral dissolution, or biofouling, which can result in formation plugging, well integrity problems, or well failure. Further, constituents in the CO2 may have different mobilities than the CO2 itself (e.g., they may partition into the receiving brine rather...
than stay with the CO₂ plume), and these constituents may present an environmental or health risk if they reach an underground source of drinking water (USDW).

**Approach**

EPRI will continue its multifaceted, multiyear research in collaboration with DOE, research organizations internationally, compressor manufacturers, and pipeline operators. Current efforts are focusing on obtaining data from pilot tests and demonstrations on the trace impurities that may remain with captured CO₂, with an early focus on the higher concentration impurities, such as H₂S (from IGCC plants), O₂, and water; later work will measure or predict potential impurity levels of solvents or solvent/sorbent/membrane degradation products. Together with its partners, EPRI will develop equations of state for the higher-concentration impurities in a high-pressure/temperature CO₂-dominated compressor environment. These thermodynamic state data are needed to design compressors for CCS applications, especially for configurations where the compressor (with its intercoolers) also is being used to remove impurities. Thermodynamic properties for the lower concentration species will be developed in out years, after EPRI or others have an opportunity to measure the types and quantities of these impurities at CO₂ capture test sites.

For advanced compression systems, EPRI will continue to monitor and report on developments and participate in projects in which EPRI can add value.

In parallel, and based on the constituent data and current CO₂ pipeline experience, EPRI will study the corrosion of carbon steels by supercritical CO₂ with varying impurity types and concentrations, consider the durability of seals and gaskets to such fluids, and ensure that thermodynamic and flow property data are available for compressor, valve, and pipeline designers.

In addition, EPRI is engaged in a multiyear research and information exchange program to determine how pure a CO₂ stream must be when delivered to an injection formation. The objective is to understand the purity that enables a target injection formation to realize its maximum injectivity and capacity, while avoiding potential exposure of USDWs to hazardous constituents that might be in the CO₂ stream. This work will be coordinated with the work that considers CO₂ purity requirements to maintain the integrity of the compression and transport systems. Initial efforts to obtain data from various CO₂ capture pilot tests and demonstrations on the trace impurities that may remain with the captured CO₂ will serve both projects.

EPRI plans to obtain the impurity concentration data from several larger pilot-scale CO₂ capture demonstrations in which it is involved or permitted to test, as well as from projects by others that are shared openly through such forums as the IEA CO₂ Capture Network.

**Impact**

By providing guidance on the purity requirements for storage, this project will enable members to avoid the:

- Costs of CO₂ stream clean-up to unnecessarily stringent levels or shortened pipeline lifetimes due to corrosion by too-high impurity levels
- Risk and cost of having to drill additional injection wells, retrofit additional equipment to the CO₂ capture plant to further clean up the CO₂ stream, or even move to a different location because constituents in the CO₂ caused plugging of an injection formation
- Risk and cost of having to remediate a USDW that has been contaminated by a hazardous species that migrated from the injection formation to the USDW.

**How to Apply Results**

Power company system engineers can use project findings on purity requirements to design or specify capture technologies that provide a CO₂ stream of the required purity for feeding into a commercial pipeline. For power plants with a dedicated transport line to a storage site, system engineers can conduct tradeoff analyses between higher-purity CO₂ and higher-grade materials.
Power company reservoir engineers and CO2 capture process design engineers can use the tools and information developed by this project to make decisions on the purity requirements needed for the storage formations under consideration and support underground injection permitting, specifically with regard to potential risks to any USDWs above the target injection formation.

### 2012 Products

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<tbody>
<tr>
<td><strong>Impact of CO2 Impurities on CO2 Compressor Technology and Pipeline Design for CCS Applications:</strong> Interim assessment of impact of major impurities in power plant supercritical CO2 with major impurities on the design of CO2 compressors and pipelines.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>CO2 Purity Requirements for Storage -- Initial Assessment of Potential Minor Constituents:</strong> Identification and acquisition of impurity data needed for reactive chemistry transport geologic models (concentrations in the CO2 stream, thermodynamic properties, solubilities, and reactive transport coefficients).</td>
<td>12/31/12</td>
<td>Technical Update</td>
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### Future Year Products

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<tbody>
<tr>
<td><strong>Initial Storage Flow and Transport Simulation:</strong> Results of first simulation (one formation type) with prediction of potential risk to a USDW due to impurities in the CO2. May include consideration of plugging by precipitation if considered a potential issue due to the type and concentrations of the impurities in the CO2. Recommendations on need for further development of models and geochemistry rate data.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Economics of CO2 Purity Specifications for Pipelines:</strong> Cost tradeoff analysis between producing higher-purity CO2 streams and using more corrosion-tolerant alloys for pipelines, pending availability by then of corrosion test results (lab and field) of varying impurity streams and pipeline alloys.</td>
<td>12/31/14</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>CO2 Compressor Technology and Pipeline Design for CCS Applications -- State-of-Technology Update:</strong> Update of 2012 report, plus summary of Workshop on CO2 Compression and Storage (follow-on to 2009 workshop).</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Flow and Transport Simulation -- Formation Type X:</strong> Results of simulation on either same or different formation than initial simulation, using enhanced model (per recommendations in 2012 report). Possible validation from field and laboratory tests.</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Flow and Transport Simulations -- Additional Formations:</strong> Results of simulations on additional formation types (e.g., per list in the Approach discussion). Initial assessment of CO2 purity requirements for different types of formations, based on potential risk to USDWs or formation plugging.</td>
<td>12/31/15</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>CO2 Compressor Technology and Pipeline Design for CCS Applications -- State-of-Technology Update:</strong> Final report on assessment of least-energy, least-cost compression and transport approaches, including new designs and energy integration of the compressor with the plant or capture system to minimize capital cost and energy demand. Update on the 2014 cost tradeoff study between purification of the CO2 stream versus using expensive corrosion-resistant pipeline materials.</td>
<td>12/31/16</td>
<td>Technical Update</td>
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<tr>
<td><strong>CO2 Purity Requirements for Storage</strong>: Recommended CO$_2$ purity requirements for different formations, overlying geologies, and potential leakage into USDWs, based on both risk assessment of potential health impacts on potable aquifers and potential for pluggage of formation pores.</td>
<td>12/31/16</td>
<td>Technical Report</td>
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Supplemental Projects

Site-specific Storage Economics for Power Plant CO2 (072087)

Background, Objectives, and New Learnings
Geologic storage of carbon dioxide (CO₂) is one of several solutions being considered to reduce greenhouse gas emissions. Economic models developed to date for geologic storage have focused primarily on compression costs associated with injection of CO₂ deep underground in rock formations containing saline groundwater. These models use the depth of injection as a proxy for the groundwater hydraulic head (or fluid pressure) in the rock that must be exceeded by the compressor before CO₂ can be injected into the subsurface. Little consideration is given in these models to the physical properties of the rock and permit conditions that constrain the rate of CO₂ injection, which in turn, controls the number of injection wells and costs. In addition, costs associated with qualifying and permitting the storage site, staged development of the CO₂ injection well field, operation and maintenance, and closure and contingency costs associated with remediation (in the unlikely event that CO₂ leakage occurred after injection started) have yet to be integrated into one cost model.

Project Approach and Summary
The purpose of this supplemental project is to develop a comprehensive economic model that integrates the costs of all aspects of CO₂ storage into one model. The model will formulate "cradle-to-grave" storage-related project costs associated with site screening, project development and site qualification, pore-space acquisition, permitting, injection operations and maintenance, long-term monitoring, closure and contingency planning, and corrective action. Up to three regionally extensive storage formations will be used as case studies to highlight the capabilities and functionality of the economic model and to compare/contrast results from rock formations with markedly different physical properties.

Benefits
The results of this project will improve our fundamental understanding of CO₂ storage costs, allowing industry to develop effective strategies for deploying carbon capture and storage should it be needed.
Potential Impact of Stored CO2 on Potable Groundwater (069583)

Background, Objectives, and New Learnings
Capturing carbon dioxide (CO2) emissions from power plants and injecting the CO2 deep underground in oil and gas reservoirs or formations containing groundwater too salty to drink is one of several options being considered to help mitigate global climate change. To provide information about this approach to the public and regulators, the industry needs to carefully study all potential environmental risks, including the potential for CO2 movement into shallow aquifers containing potable groundwater and subsequent contamination. With proper site selection and a regulatory framework designed to oversee, monitor, and control risk, the possibility of CO2 migration from target storage reservoirs into potable water aquifers is considered to be small. Nevertheless, the potential impact that CO2 could have on potable groundwater resources and the resulting cost of remediation warrant evaluation.

EPRI performed an initial field study, using a shallow groundwater aquifer, to investigate whether sequestered CO2 released from a hypothetical geologic storage reservoir would have an adverse impact on underground sources of drinking water. Although none of the dissolved metals exceeded the primary drinking water standards established by the EPA, these results cannot be considered definitive, because the site conditions were not entirely representative of an underground source of drinking water. Additional in situ field studies are needed on representative aquifers.

Project Approach and Summary
A small-scale injection of CO2-laden groundwater will be conducted and monitored at Mississippi Power Company's Plant Daniel near Escatawpa, Mississippi. The injection will take place in a confined freshwater aquifer, where the injection has no possibility of affecting water-supply wells in the area. Using an in situ approach ensures that the CO2-laden groundwater is subjected to the complex oxidation-reduction (redox) conditions that persist in the subsurface.

A hydrogeologic investigation of the study site will be performed to collect soil and groundwater samples for determination of physical and chemical properties. A well field will be installed to inject CO2-laden groundwater, pump groundwater to control the distribution of CO2 in the subsurface, and monitor for changes in groundwater quality. In situ redox conditions, which have a large influence on water quality, will be maintained by pumping groundwater from the aquifer, dissolving CO2 in the groundwater at the land surface, and re-injecting the CO2-laden groundwater back underground — all within a closed-loop system that prevents interaction with the atmosphere. Groundwater samples will be collected and analyzed for major dissolved constituents prior to, during, and after injection to measure the impact that CO2 has on water quality.

Groundwater flow and reactive transport models developed at Lawrence Berkeley National Laboratory will be used to design the experiment, predict the outcome, and interpret the results, building confidence that validated models will be available.

Benefits
The results of this project will improve fundamental understanding of CO2 fate, transport, and potential impacts, so that industry can develop effective remedial strategies.
Combustion Turbine (CT) and Combined-Cycle (CC) O&M - Program 79

Program Overview

Program Description
The asset value of natural-gas-fired gas turbines, especially in combined-cycle plants, is on the rise, driven by their inherent efficiency, emissions, operational characteristics, broader market fit with a forecasted affordable fuel supply, and complementary role covering load swings such as those from intermittent renewables. Cycling and high-temperature operations adversely affect combustion turbine component life, as well as plant reliability and availability. The risks associated with hot section durability, compressor failures, rotor cracks, and combustor dynamics must be cost-effectively managed. Improved operational flexibility, in areas such as dry low-NOx (DLN) combustor turndown and plant startup, would help plants address load demands. Beyond the gas turbine, combined cycles have a broader range of concerns, including selective catalytic reduction (SCR) catalyst deactivation, steam turbine-generator reliability, plant performance degradation, faster startups, and load response to better accommodate intermittent power sources from wind and solar.

The Electric Power Research Institute’s (EPRI’s) Combustion Turbine (CT) and Combined-Cycle (CC) O&M program (Program 79) provides comprehensive resources to address the operation and maintenance (O&M) needs of conventional and advanced CTs, related emissions control equipment, and combined-cycle rotating equipment.

Research Value
Members of this program can use the R&D to manage equipment risks through root cause analyses and engineered solutions; reduce life-cycle costs through repair technology and improved component design; and enhance overall plant operational flexibility by reducing combustor issues, mitigating cycling damage, and increasing performance. Specifically, members can:

- Manage major O&M risks not typically covered by OEM and third-party service agreements
- Improve O&M costs through in-depth understanding of O&M issues at the model/sub-model-specific level, and significantly reduce overall life-cycle costs without increasing failure risks
- Gain expert assessments of original equipment manufacturer (OEM) and independent offerings in addition to O&M recommendations
- Benefit from O&M experience and resources through collaborative interactions

Approach
Program activities address monitoring and inspection, repair technique improvement, component life prediction, and plant O&M management tools. Model-specific design features are directly addressed in product development. Members use the R&D for:

- Risk management (early detection, root cause, and solutions) R&D uses in-depth studies of high-risk component issues to identify root cause failure mechanisms and to develop and demonstrate corrective/damage mitigation solutions.
- Research into O&M improvements (life prediction, component design, and repair) research provides model-specific repair, procurement, and damage-tracking guidelines for hot-section, combustor, and compressor components.
- Operational flexibility (capacity, performance, combustion dynamics, and emissions) R&D produces techniques for improving interrelated machine operational characteristics, such as tuning and turndown of DLN systems and mitigating cycling damage.
- Plant productivity support tools and training provide O&M cost analysis software, maintenance guidance, and overhaul planning tools for different CT models and select combined-cycle equipment, as well as training courses for applying EPRI products.
Accomplishments

EPRI’s Combustion Turbine and Combined-Cycle O&M program has provided high-quality technical evaluations and products to support better operations and maintenance for more than 30 years, including:

- Model-specific repair guidelines for widely used 50/60-Hertz (Hz) machines
- Replacement part procurement guidelines for D/E- and F-Class models
- Compressor and rotor root-cause analysis and O&M solutions
- O&M guidance for DLN combustor systems and segmented feed pumps
- SCR and CO catalyst deactivation assessment and improved emission controls tuning

Current Year Activities

Program R&D for 2012 will seek to mitigate advanced machine dependability issues and reduce conventional machine O&M costs. Specific efforts will focus on:

- Root causes of recurring failures and durability shortfalls
- Cost-effective approaches for addressing compressor, combustor, and rotor dependability and useful life assessment tools
- New and updated repair and procurement guidelines for 50/60-Hz models
- Auxiliary and combined-cycle equipment O&M: SCR catalyst management; steam turbine and electric generator issues; and inlet air filtration improvements

Estimated 2012 Program Funding

$3.2M

Program Manager

John Scheibel, 650-855-2446, jscheibe@epri.com

Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P79.001</td>
<td>Risk Management: Early Detection, Root Cause and Solutions</td>
<td>In-depth investigations and guidelines address high-risk component failure root cause mechanisms. Corrective solutions and damage mitigation techniques are developed, evaluated, and demonstrated.</td>
</tr>
<tr>
<td>P79.002</td>
<td>O&amp;M Improvements: Life Prediction, Component Design and Repair</td>
<td>The project provides model-specific repair, procurement, and damage-tracking guidelines for hot section, combustor, and compressor components.</td>
</tr>
<tr>
<td>P79.003</td>
<td>Operational Flexibility: Capacity, Performance, Combustion Dynamics and Emissions</td>
<td>This project provides techniques for improving interrelated machine and plant operational characteristics, such as emissions and turndown of DLN systems, part-load performance, or full-load megawatt capacity production.</td>
</tr>
<tr>
<td>P79.004</td>
<td>Plant Productivity Support Tools &amp; Training</td>
<td>This project provides O&amp;M cost analysis software and overhaul planning tools for different models, as well as combined-cycle plant equipment O&amp;M guidelines and special studies, and develops training courses to assist with the application of EPRI products.</td>
</tr>
</tbody>
</table>
P79.001 Risk Management: Early Detection, Root Cause and Solutions (067357)

Key Research Question
The effective operation of complex, tightly integrated combustion turbines (CTs) requires astute monitoring, regular inspection, understanding of the critical damage mechanisms and root causes, and engineered solutions to maintain high availability and reliability. This requirement is particularly true for advanced machines, in which cascading failures can cause more than $10 million in equipment damage. Similar concerns exist for high-pressure steam turbines (STs) and electric generators used in combined cycles. These types of major equipment risks usually are not addressed by service agreements and only are partially covered by insurance.

Approach
This project helps members with early detection of incipient damage, as well as in-depth understanding of damage mechanisms and the underlying root causes driving accelerated deterioration and increased risk of outright failure.

- Cost-effective risk management needs to be tailored to the specific machine model and issue in the compressor, combustion system, or hot section. This project develops and validates inspection and monitoring techniques, collects field experience, characterizes component design features, develops detailed engineering models, and evaluates damage mitigation and corrective design measures.
- In the compressor, work is aimed at understanding and mitigating the impacts of extensive rubbing, erosion/corrosion, deposit buildup, foreign object damage (FOD), stall/flutter flow excitations, and clashing contributing to blade and stator failures.
- In the combustion system, techniques are being developed to detect dry low-NOx burner instabilities, leading to fuel nozzle failure and downstream hardware damage.
- In the turbine hot section and rotor, material testing and design analyses are used to assess risks from high-temperature creep/oxidation, thermo-mechanical fatigue cracking, and reduced fracture toughness/embrittlement of costly superalloy and CrMoV components. Detailed component failure and stress analysis is often covered in supplemental projects.
- In the electric generator and bottoming steam cycle, risks from end winding failures or fatigue cracking of the long-last steam turbine blades are addressed at the root cause analysis level, and corrective measures are proven by plant testing and experience.

Impact
- Mitigate damage by using improved monitoring and inspection techniques to provide advance notice to CT owners of abnormal conditions and the opportunity to take countermeasures.
- Cost-effectively reduce the risk of high-impact failures by understanding damage mechanisms and their root causes, and adjusting maintenance accordingly.
- Develop, evaluate, and demonstrate engineered solutions, including design modifications that effectively address the root causes.
- Determine the useful economic life of high-valued components on a sound, independent engineering basis.

How to Apply Results
Investigation reports of root cause failure and damage provide technical background to define flaw size for inspection, adjust operating practices, and evaluate possible design modification. An engineered solution may require the involvement of the OEM, repair shop, or other service provider. Monitoring techniques are customized to the model type and plant configuration. The plant or remotely located monitoring center installs the software with appropriate connections to the plant process data historian.
2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Rotor Life Evaluation - Update:</strong> This report provides guidance on evaluating the condition of life-limiting CT turbine and compressor rotors subject to long-term deterioration from creep, embrittlement, and low-cycle thermal fatigue mechanisms. The project develops new inspection techniques and material property data using conventional destructive and small sampling techniques, such as the small punch test, on retired components.</td>
<td>01/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Demonstration of Damage Mitigation Techniques: Monitoring Experience:</strong> The effectiveness of new coatings, component modifications, remote inspection, or monitoring techniques is demonstrated and validated. Additional R&amp;D may be identified to further improve or refine component redesigns or O&amp;M procedures. Ongoing work focuses on field validation of online detection of DLN combustor damage using an EPRI developed health indicator incorporated into the dynamics monitoring system. Planned new work will monitor compressor damage, such as from rotating stall or surge, that may produce field-observed incidents of airfoil clashing.</td>
<td>01/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Component Failure Investigations and O&amp;M Risk Mitigation Guidance:</strong> For the turbine, compressor, combustor, and rotor components, deterioration and failure are investigated for specific models. For combined cycles, electric generator windings and steam turbine flow path failures, such as last stage L-0 cracking, are investigated. Metallographic analyses, material property testing, and stress modeling, coupled with machine operating characteristics, are used to develop and screen possible solutions. Recent focus has been on compressor rotating and stationary compressor airfoil cracking.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td><strong>Rotor Life Evaluation - Update:</strong> Guideline addresses general approach to evaluating turbine and compressor rotor life.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Demonstration and Validation of Component Modification and Damage Mitigation Techniques:</strong> Novel techniques to detect damage and implement mitigation measures are covered.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Component Failure Investigations and O&amp;M Risk Mitigation Guidance:</strong> Failure root cause analysis of components of wide interest to gas turbine operators.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
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</table>

**P79.002 O&M Improvements: Life Prediction, Component Design and Repair (067358)**

**Key Research Question**

Combustion turbines require extensive repair and refurbishment at predetermined intervals due to very high-temperature operation. Superalloy blades, vanes, and combustion hardware depend on effective repairs to achieve their stated economic life. Due to the high cost of repairs (for example, an F-class first-stage blade replacement can cost $2 to 4 million per row), the need for in-depth guidance is critical. Fallout rates (i.e., for parts deemed not repairable at the prescribed strip/recoat interval) have exceeded 50% for certain high-temperature combustion turbine models. For mature designs, extending run intervals may be possible with design and material testing qualification. A new generation of low-conductivity thermal barrier coatings (low-k TBC) potentially offers extended operating life or enhanced performance benefits. Compressor O&M issues
include rubbing, tip cracking, foreign object damage, erosion, corrosion, aerodynamic stall/flutter, and surge. Repair service providers and aftermarket parts suppliers may offer competitive alternatives to the original equipment supplier for innovative design/repair solutions.

**Approach**

Effective management of compressor, combustion, and hot-section life-cycle costs focuses on three elements: optimizing the maintenance interval, extending service life by repair, and obtaining lower-cost/longer-life replacement hardware. EPRI offers R&D supporting all three areas:

- Damage tracking guidance is based on extensive durability analyses that provide objective estimations of creep, oxidation, and thermal mechanical fatigue damage to specific components locations as a function of operation. EPRI maintains and continues to expand a series of CT component repair guidelines covering combustion/hot-section hardware for 50/60-Hz conventional and advanced models. Currently available model-specific volumes cover: GE 7B, 6B, 7FA, 9FA, 7E/EA, 9E; Siemens-Westinghouse W501A-D, W501D/D5A, W501F, V84.2, V94.2, V84.3A, V94.3A; Alstom 11N2, GT24, GT26; and Mitsubishi M501F, M701F.

- A series of procurement guidelines for replacement of superalloy components provide technical criteria for nondestructive examination, acceptable coatings, qualification/approval of master heats, dimensional conformity, manufacturing and heat treatment, metallurgical requirements, and quality assurance. Also included is repair technology development using novel welding, brazing, and geometry modifications.

- For the compressor, EPRI develops and translates into plant-oriented guidance the following areas: understanding the influence of inlet guide vane scheduling and aerodynamic conditions on blade dynamics, surface treatments for erosion/corrosion resistance, and methods to address attachment fretting and airfoil impact damage. To facilitate the application of guidelines, EPRI routinely issues reports surveying the capabilities of repair shops and aftermarket parts suppliers.

**Impact**

- Reduce fallout from repair cycles and possibly extend overall economic life using the damage-tracking guidance to optimize maintenance intervals.
- Achieve cost savings from competent, cost-effective refurbishment services made possible by the repair guidelines.
- Reduce replacement hardware costs by procuring more durable designs and competitive bidding.
- For those machines covered by extended service agreements, EPRI products play a role in overseeing quality repairs, establishing objective run/scrap criteria, and factoring in technology improvements into the overall lifecycle management.

**How to Apply Results**

Repair and procurement guidelines, as well as related supplier capability surveys, are used to support competitive bidding. The guidelines are designed to be incorporated into a technical specification bidding document. The repair criteria are used to safely guide refurbishment and identify key quality issues. Damage tracking guidance can be used to make manual estimations of component maintenance intervals or incorporated into the plant's automated monitoring system. Project information also is useful in managing long-term service agreements. Compressor guidance is aimed at supporting field inspection and air flow path maintenance.
## 2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>CT Repair Guidelines: New and Updated Model-Specific Volumes:</strong> Eighteen gas turbine models are covered in separate repair guideline volumes. Each volume provides individual component specifications, addressing the specific design features and repair considerations for hot-section blades and vanes and combustion hardware. Guidelines routinely are updated to include the latest design features, restoration dimensions, typical component damage, and repair techniques.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Component Durability Analysis and Damage Tracking:</strong> Component durability models provide insights into relating plant operations to observed hot-section damage. Local stress and temperature profiles closely relate to tip oxidation, leading-edge distress, and trailing-edge and platform cracking. Service-aged component testing and field experience are incorporated in updated damage tracking software. This information is used to improve repair procedures, optimize service intervals, and assess design modifications.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Repair Shop and Alternative CT Component Supplier Capabilities Update:</strong> EPRI routinely surveys repair shops and alternative parts supplier capabilities. Reports cover both North American and international repair service providers and alternative parts suppliers. Topics include experience level with specific model parts, unique component design features or repair approaches, and near-term plans of new offerings, especially related to E- and F-class models.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Advanced Repair Development and Qualification:</strong> A new generation of low-conductivity thermal barrier coatings (TBC) enable the components to operate at lower metal temperatures or increased turbine inlet temperature. Coupon testing to establish data critical to quality parameters and performance characteristics will be performed, leading to field testing. Additional repair development also is planned for qualifying new high-strength brazing compositions and for evaluating the effectiveness of alternative heat treatments used for reconditioning superalloy components.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Compressor Airfoil Trimming Guideline:</strong> Compressor airfoil tips and leading and trailing edges can be damaged by foreign objects, rubbing, and liberated upstream component pieces. For light to moderate damage, the airfoil may be trimmed in lieu of replacement and thus avoid cost and outage time. The 7FA guideline begun in 2011 defines appropriate trimming practices based structural analysis for rotating blades. Plans are to extend the guideline to selective inlet stationary vanes and develop additional model-specific guideline versions.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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## Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>CT Repair Guidelines: New and Updated Model-Specific Volumes:</strong> Repair guidelines primarily focused on model-specific combustor and hot-section components.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Procurement Guidelines for Improved Components: New and Updated Model-Specific Volumes:</strong> Component procurement guidelines aimed at replacing hot-section hardware.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Component Durability Analysis and Damage Tracking:</strong> Independent analysis of hot-section durability issues and maintenance interval guidance.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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</tbody>
</table>
**Advanced Repair Development and Qualification**: New repair technology to help extend overall component useful life.

**Planned Completion Date**: 12/31/13

**Product Type**: Technical Update

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**P79.003 Operational Flexibility: Capacity, Performance, Combustion Dynamics and Emissions (100579)**

**Key Research Question**

Plants required to cycle generally suffer from accelerated degradation, reduced availability, and increased O&M costs. The challenge in cycling combustion turbine plants lies in the interrelationship of capacity, performance, and emissions combined with high transient stresses in hot-section components. The combustion system often is the limiting factor in turndown, while thick-walled components in downstream combined-cycle equipment can slow startups. The dry low-NOx (DLN) combustor is particularly sensitive to changes in fuel quality, ambient conditions, component ware, and calibration. Improving the gas flow interface between the gas turbine and the heat recovery steam generator would further help lessen damaging vibratory pulsations and thermal maldistributions.

**Approach**

This project examines the impact of design limitations on various operational flexibility issues, leading to solution developments and field validation. The near-term focus is on combustor dynamics and emissions of particular concern for the DLN and conventional diffusion-flame designs using extensive water/steam injection. Emissions produced during startup, shutdown, low-load, and load transients are an emerging operational flexibility challenge. Techniques for monitoring damaging dynamic events and procedures for improved tuning are helping to enhance the performance of premixed combustion systems. All aspects of combustion maintenance, including nozzle flowing, optimal maintenance intervals, and extended service hardware modifications, will be addressed. A new project focus involves developing and demonstrating emerging automated tuning techniques and related sensing devices. The project has developed extensive background information about capacity enhancement techniques, such as foggers, chillers, and evaporative coolers. Incorporating thermal storage ice production with inlet chillers to take advantage of off-peak power is being investigated.

**Impact**

- Improve O&M of conventional and dry low-NOx combustors by using model-specific guidance.
- Understand the limitations of fuel interchangeability and possible issues with broader fuel supply sourcing.
- Boost electricity production through extensive background information on capacity and storage enhancement techniques.
- Improve overall operational flexibility by introducing field-validated plant modifications.

**How to Apply Results**

The guidelines and reports are used in conjunction with combustor inspections and improvements to system operation, such as overseeing the regularly scheduled refurbishment or adjusting fuel splits. Reports provide the understanding necessary to anticipate possible fuel impacts and methods to accommodate wider quality variations via monitoring, combustor adjustment, and equipment modifications. Reports also help identify possible equipment and control modifications to enhance certain aspects of improving plant operational flexibility.
### 2012 Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>DLN Combustor Fuel Nozzle Flow Testing:</strong> DLN combustor performance, such as emission and dynamics, is highly sensitive to proper re-flowing procedures typically performed by the repair shop. EPRI reference flow orifices have been fabricated to emulate DLN fuel nozzle effective flow areas — the primary criteria for fuel nozzle reconditioning. This project will demonstrate the use of the EPRI reference orifices in improving the accuracy and precision of shop re-flowing procedures.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Combined Cycle Performance Monitoring and Recovery:</strong> This generic combined-cycle guideline defines how to successfully design, implement, and manage a plant heat rate monitoring and recovery program, including key plant and major component efficiency indicators; instrumentation and data needed to determine actual vs. expected conditions; and diagnostic flow charts to determine likely causes of performance deficiency.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>DLN Combustor Auto-Tuning Field Test:</strong> DLN combustors typically require periodic re-tuning to maintain performance within a narrow operational emissions-dynamics acceptance window. Auto-tuning is an emerging technique to maintain the combustor within the acceptance window by automatically trimming the combustor fuel splits. This project addresses the implementation and extended operational experience with this advanced combustor control feature.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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### Future Year Products

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<tbody>
<tr>
<td><strong>Plant Operational Flexibility Modifications:</strong> Novel plant modifications to improve aspects of operational flexibility.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>DLN Combustor O&amp;M Guidelines: New and Updated:</strong> Guidelines address proper maintenance and tuning of dry, low-NOx combustors.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Capacity Enhancements: New Techniques and Operational Impacts:</strong> Techniques and related experience to offset electricity production derates and enhance peak output.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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</table>

### P79.004 Plant Productivity Support Tools & Training (100574)

#### Key Research Question

Plant managers, engineers, and operators must continually re-examine the effectiveness of their O&M procedures and identify areas for improvement. These procedures include maintenance timing, risk management, staff renewal, parts sparing, overhaul planning, and optimal budgeting. Information from outside the company often is required for effective benchmarking and to help define effective, achievable goals.

#### Approach

This project addresses some of the key combustion turbine/combined-cycle O&M concerns not covered in other parts of the program. Resources provided include:
• A series of O&M guidelines addressing gas turbine island and select combined-cycle equipment that includes axial compressor performance, predictive maintenance implementation, selective catalytic reduction (SCR) systems, and segmented feed pumps.
• The INTURB CT owner’s directory, which facilitates contacting peers to share information about model-specific reliability. The database contains information on more than 5,400 sites.
• A series of software packages, called the Gas Turbine Overhaul Plan (GTOP), that provide model-specific detailed disassembly, inspection, and re-assembly task breakdowns. Current GTOP models include the GE Frame 7B, 6B, 5, 7FA, 9FA; Siemens-Westinghouse W501AA-D, V84.2; and Alstom GT11N/N1, N2, 11D, with others planned.
• The CTCC O&M Cost Analyzer, which enables overall cost assessment of maintenance strategies, including service agreements, operational cost impacts, and self-maintenance options.
• Training courses and workshops that help members apply the program products.

Impact
• Manage outages more effectively by using a detailed, model-specific overhaul plan with task-by-task breakdown structure.
• Benchmark and develop best practices by applying equipment O&M guidelines.
• Develop detailed modeling and costs for examining operational impacts and changes in maintenance strategies using the CTCC O&M Analyzer.
• Identify and troubleshoot a range of equipment problems by employing the plant equipment guidelines.

How to Apply Results
GTOP software is used directly in the outage planning process. The task database can be transferred to other popular maintenance management software. O&M guidelines are kept at the plant as a readily available reference. EPRI training improves staff general technical understanding and application of specific EPRI products. The CTCC O&M Analyzer typically requires two to three hours of web-based training, after which staff can evaluate specific machine life-cycle economics.

2012 Products

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<tr>
<td><strong>CTCC O&amp;M Cost Analyzer: Update Version:</strong> Excel® spreadsheet-based software estimates the O&amp;M costs for simple-cycle and combined-cycle plants for user-specified operating scenarios. CT model-specific maintenance costs are based on component replacement and repair costs, life estimates, and maintenance intervals. This product is shared with EPRI Program 80 — New Combustion Turbine/Combined-Cycle Plant Design and Technology Selection.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Equipment O&amp;M Guidelines and PM Basis:</strong> O&amp;M guidelines have been developed for SCR and CO catalyst management, electric generator endwindings issues, and segmented boiler feedpump. Additional guidelines are planned for air inlet filtration and other CT auxiliary equipment. Guidelines support the development of preventive maintenance (PM) basis templates, which help implement effective maintenance actions. Reliability, Availability, and Maintainability (RAM) statistics for combined-cycle plant equipment are provided to help evaluate risk/benefit O&amp;M tradeoffs. This project is coordinated, including selected shared product development, with EPRI Program 104 — Generation Maintenance Application Center.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</tbody>
</table>
**Tech Transfer: Training Courses:** Training courses and webcasts support the technology transfer of program products. A Hot Section Life Management course supports the implementation of repair guidelines, damage tracking module, and procurement guidelines for the replacement of superalloy parts. Other courses and webcasts support the maintenance of dry, low-emissions combustors, including tuning procedures, rotor life evaluation, and software orientation for the use of the CTCC O&M Cost Analyzer and GTOP products.

**Gas Turbine Overhaul Plan (GTOP): New and Updated:** A database of approximately 300 tasks covers detailed steps in gas turbine disassembly, inspection, and re-assembly suitable for managing a combustion inspection, hot-gas-path inspection, or major overhaul. A complementary version addresses all major combined-cycle equipment. Man-hours, tooling, and craft type are included in each task. The software platform is Microsoft Project®, and the task database is transferrable to other planning software. Maintenance procedures and inspection forms can be linked to create a complete overhaul record.

**Future Year Products**

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<tbody>
<tr>
<td><strong>CTCC O&amp;M Cost Analyzer: Update Version:</strong> Software to estimate O&amp;M costs for simple-cycle and combined cycle plants.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Equipment O&amp;M Guidelines: New and Updated:</strong> Maintenance guidelines addressing select combined-cycle equipment.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Tech Transfer: Training Courses:</strong> Training courses and webcasts supporting program products.</td>
<td>12/31/13</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Gas Turbine Overhaul Plan (GTOP): New and Updated:</strong> Model-specific software to support gas turbine major overhauls.</td>
<td>12/31/13</td>
<td>Software</td>
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</table>
**Supplemental Projects**

**Gas Turbine Rotor Life (066745)**

**Background, Objectives, and New Learnings**

Gas turbines (GTs) are used in simple-cycle configuration to supply peaking power generation service. These machines acquire many cycles but relatively few hours of service. They also are idled for extended periods and thus are subject to corrosion from condensation. GTs in combined-cycle configuration can be deployed in either daily cycling or more baseloaded service. As such, combined-cycle rotor life may be governed by hours of operation or a combination of hours and starts.

GT rotors typically are inspected during hot gas path and major maintenance intervals when casing covers are removed. The original equipment manufacturer (OEM) typically will assist in these inspections and will judge whether the rotor is suitable for continued service. Sections of the rotor may be deemed nonserviceable after 100,000 to 250,000 hours or 2500 to 5000 starts. The impacts of an extended outage for a rotor rebuild may be mitigated by using a pooled spare rotor—if one is available.

OEMs have been notifying GT owners that rotors used on high-hours machines should be shipped off-site and disassembled for extensive inspection. Pending inspection results, a limited operation extension may be granted. For high-starts machines, the recommendation often is to retire them without inspection. The engineering basis for rotor operational extension or retirement is unclear, with little field experiential data to establish a quantifiable risk.

**Project Approach and Summary**

The overall work scope is structured around two major tasks: Rotor Life Inspection and Evaluation Guidelines, and Model-Specific Component Evaluation. Life prediction procedures are developed for the particular rotor design and material, with particular emphasis on rim-blade interface, bolt holes, and center bores or alternatively welded rotors. The component focus can be adjusted to suit a specific machine operating mode, anticipated issues, or inspection results. Where available, destructive mechanical testing of retired components may be included to further quantify material degradation.

**Benefits**

Results from this project will provide GT owners with procedures and technical information to objectively evaluate the condition of their GT rotors. Rotor rebuild/replacement, along with the associated outage, is estimated to exceed $6 million per machine.
Reducing Life Cycle Costs for Gas Turbine Hot Section Components (064708)

Background, Objectives, and New Learnings
Gas turbine (GT) combustion parts and the downstream hot section vanes and blades routinely are inspected, refurbished, and replaced. The cost of extensive maintenance associated with the gas turbine life-cycle can exceed the initial equipment cost by as much as a factor of three. Each model type has design-specific features that require specialized knowledge to effectively manage machine O&M. For instance, each turbine model has unique blade designs made of superalloy thin-walled castings requiring complex internal cooling, oxidation, and thermal barrier coatings to survive in a high-temperature environment.

Faced with such specialized hardware, gas turbine owners seek to reduce O&M expenses without increasing risk by optimizing all the activities and costs related to the inspect/repair/replace life cycle. To effectively support this goal requires model-specific, objective knowledge of component design, repair, and degradation mechanisms experienced in their own units.

To meet this basic need, EPRI has developed core competencies in hot-section design analysis and repair procedures and applied them to different CT models. EPRI collaborative projects supported by the owner/operators of 50- and 60Hz models have created an extensive knowledge base addressing widely used conventional and advanced engines.

Project Approach and Summary
The general approach for each model-specific project is optimize the hot-section economic life cycle at either the plant or fleet level according to how the parts inventory is managed. Tools are developed to manage critical aspects of the life cycle: repair procedures, accumulated damage tracking, and replacement/upgrade procurement guidelines. Component testing may be included if suitable specimens are available.

Benefits
The technical knowledge base provided by this project enables participants to more effectively manage gas turbine hot-section life-cycle costs and the maintenance-related technical issues. The technical issues are equally relevant to both OEM and independent O&M providers. If the knowledge base is used as part of an overall maintenance strategy, participants can realize cost savings of 25% or more. These savings can range from $500,000 for conventional D/E-Class machines to as much as $3.2 million for advanced F-Class machines per hot gas path, depending on model and operating duty cycle.
Combustor Dynamics Monitoring for Improved Gas Turbine Reliability (072056)

Background, Objectives, and New Learnings

This project is a continuation of EPRI R&D that developed a basis for detecting combustion system failures in dry, low-NOx (DLN) gas turbines, based on analysis of dynamic pressure data. This detection analysis approach is a significant advancement over the threshold detection methodologies currently available with existing combustion dynamics monitoring systems (CDMS). This field test effort project continues this work by applying these methods to additional host site gas turbines. It will focus on the refinement of these methods of failure detection for DLN combustion systems while minimizing false alarms alerts due to sensor failures, ambient condition changes, and control system variations.

The objectives of this project are to provide host sites with an on-line tool to improve operational flexibility and avoid DLN combustion system failures; to investigate any data anomalies and identify potential or emerging problems over a 24-month period; and to generate guidelines to avoid DLN combustion system failures.

The knowledge developed by this project can provide gas turbine operators with information to improve operational flexibility and avoid further in-service failures. This knowledge will assist in avoiding DLN combustion system failures and reduce operational risks. The results will be incorporated in a series of EPRI design and O&M guidelines that address increased combinedcycle operational flexibility.

Project Approach and Summary

The EPRI diagnostic tool will be installed in the host site’s existing combustor monitoring system. The diagnostic data will be monitored over a 24-month period. The plant receives regular status reports and alerts of impending combustor system malfunctions.

Benefits

Combustor dynamics monitoring provides improved diagnostic capability and risk avoidance. The EPRI diagnostic tool provides advanced warning beyond the conventionally supplied combustor monitoring system.
SCR Catalyst Replacement Options for Gas Turbine/Combined Cycles (072057)

Background, Objectives, and New Learnings

Selective catalytic reduction (SCR) technology for controlling nitrogen oxides (NOx) is broadly applied to natural gas-fired combustion turbines, operating in combined cycle. The SCR performance depends on numerous design and operating variables, including catalyst activity (K). Ideally the SCR could run for an indefinite period of time; however, factors such as trace metal deposition will cause the catalyst to deactivate. A catalyst is considered to be at end-of-life when the required NO removal cannot be achieved, or can be achieved only with significant residual NH₃ (ammonia slip). The widespread industry commitment to SCR technology is now reaching a level of maturity, where catalyst is reaching the end-of-life, and plants are now considering options to add, replace, or regenerate catalyst.

This project evaluates the least-cost way of maintaining the NO-removal capabilities of SCR systems, as installed in natural-gas-fired combustion turbines operating in combined cycle. In the context of this discussion, the NO-removal capabilities are the control of NO, without excessive ammonia slip, for a minimal gas pressure drop.

The knowledge developed by this project will assist in understanding the gas turbine emission control system configurations(s) and fine-tune the EPRI research specific to current best practices, vendor capabilities, and SCR catalyst system design improvements.

Project Approach and Summary

The approach in this project is to evaluate the cost and performance of three catalyst management options. Cost and performance data will be solicited from catalyst suppliers and regenerators. Notably, only new catalyst is considered commercially proven. The two major providers of regeneration services have never commercially “regenerated” catalyst for natural-gas-fired combustion turbines. Although one catalyst supplier offers an ammonia destruction catalyst, experience is limited to one, small combined-cycle unit. Performance has not been thoroughly documented. Consequently, there is uncertainty in these approaches.

A host site or sites for an engineering and risk assessment of these options will be defined. The details of the SCR design — combustion turbine process conditions, specifics of the HRSG — will be established, as well as the geometric details and activity of the catalyst.

Benefits

The results will assist gas turbine owners and operators in their investigation into the selection SCR catalyst system designs alternatives and will directly benefit the public because it lowers environmental emission levels and future risks of a power interruption or power outage due poorly functioning emission control technologies.
Combined Cycle Performance Recovery and Improvement (072058)

Background, Objectives, and New Learnings
The benefits of improved performance of combined-cycle power plants continue to grow as the costs of fuels and emissions rise, and the possibility of a carbon dioxide cap-and-trade program looms on the legislative horizon.

The mode of operation for many combined-cycle units has changed, whereby they spend more time on-line with higher capacity factors. Thermal performance now has a much larger effect on the plant’s economics.

This project will compile a report, promulgating both the methodology and the technical details of a performance improvement and maintenance program for equipment-specific combined power plants.

Project Approach and Summary
To produce a report that extends the EPRI generic Combined Cycle Performance Monitoring and Recovery Guideline to equipment-specific combined-cycle configurations and draws in actual plant experience.

The steps in developing this guide include:
- Review of existing combined-cycle plant performance assessment guidelines, publications, and training courses
- Review of utility best practices for combined-cycle plant performance assessment

The report will address both the programmatic and technical elements that comprise a performance monitoring and improvement program, including:
- Heat Rate Basics
- Equipment-specific Combined Cycle Components
- Performance Parameters and their relationship to Plant Heat Rate
- Instrumentation Requirements
- Regular, Periodic Actions to Maintain Good Plant Performance
- Hardware and operational modifications to improve performance

The report will provide many benefits, including methods for equipment-specific performance assessment, charts for root-cause diagnosis of performance issues, and identification of corrective action for improved performance of combined cycle power plants.

The application of project results will allow plant owners and operators to:
- identify sources of performance degradation
- define key performance recovery activities
- quantify resulting performance improvements

Benefits
The benefits of heat rate reduction are substantial. Lower fuel costs directly affect the bottom line. In addition, heat rate improvement is the only commercially proven and the most cost-effective control for lowering CO2 “on the margin.” And all other emissions are also lowered on a ton/MW basis.

For example, a 1% heat rate reduction at a typical 500-MW natural gas-fired combined cycle plant, operating at 50% capacity factor, can cut CO2 emissions by 10,000 tons/year, which equates to $200,000 if a $20/ton CO2 tax is enacted. The plant also will experience more than $700,000 in fuel savings for the same 1% improvement in heat rate, based on a fuel cost of $4/Mbtu.
New Combustion Turbine/Combined-Cycle Plant Design and Technology Selection - Program 80

Program Overview

Program Description

Gas turbines and combined-cycle plants increasingly are being selected for new generation additions and replacements for retired plants. Electrical capacity and generation from natural gas fuel are forecasted to increase in the coming years due to favorable gas supply availability. Recently, gas supply reserves have been revised upward, based on significant additions from shale formations and new liquefied natural gas (LNG) sources. Competitive fuel prices have resulted in increased dispatch of combined-cycle plants. Favorable gas pricing also has renewed interest in distributed generation and cogeneration opportunities with gas turbines. Combustion turbine-based plants often are selected due to their lower capital costs compared to coal and nuclear energy, and their capacity typically is used to complement intermittent wind and solar generation. Gas turbine and combined-cycle technologies continue to evolve, providing significant efficiency gains and relative improvements in installed cost. These factors, combined with a general trend towards less-carbon-intensive generation, portend an expanding role for gas turbines and combined-cycle plants in the coming decades.

Informed decisions about gas turbine technologies and plant designs are especially important because design choices can have a profound impact on operability and performance. Technology selection affects efficiency, emissions, availability, maintainability, and durability. Air and water environmental control technologies are needed to meet regulatory requirements. The ability to fire fuels of variable composition while meeting emission constraints is important in locations that may receive natural gas or LNG from multiple sources. Flexible operational capabilities are needed for optimal plant dispatch, and planners need to understand coming trends and potential improvements for future growth. Plant engineering designers are confronted by a growing number of combustion turbine/combined-cycle (CTCC) plant offerings with unique heat recovery steam generator (HRSG) and steam turbine configurations, aimed at particular market missions (peaking, intermediate/cycling, and baseload). Information about and analyses of factors affecting these performance parameters are key to achieving a design optimized on specific generation needs.

The Electric Power Research Institute’s (EPRI’s) New Combustion Turbine/Combined-Cycle (CTCC) Plant Design and Technology Selection program (Program 80) provides the information and analysis needed to select combustion turbine technologies and specify combined-cycle plant designs for today’s new generation requirements while planning for future technological advances.

Research Value

The research in this program helps engineers and project developers select and specify appropriate equipment for new plants that have the flexibility to start quickly, operate efficiently at varying loads, and fire fuels of varying composition while meeting regulatory emission limits. Improved gas turbine plant operation is achieved through an overall life-cycle approach, which includes a balanced understanding of capital and O&M costs, performance improvements, and technical risks associated with new high-efficiency turbine designs and the market contexts in which they operate. The program focuses on identifying risk issues and addressing the most significant plant design improvements that differ from the previous combined-cycle build-out. Benefits include:

- Optimal plant technology selections for generation market niche: distributed generation, peaking, cycling, intermediate, or baseload;
- Managing technology risk helps control operation and maintenance expenditures; and
- Objective, expert assessment of technology trends and worldwide experience can improve procurement decisions.
Approach

Up-to-date information and evaluations enable better procurement decisions and help minimize costs while optimizing plant performance, reliability, and operational flexibility for simple-cycle and combined-cycle combustion turbine plants.

- Document current information from EPRI durability/failure analyses, industry contacts, conferences, periodicals and news releases on industry trends, new equipment offerings and capabilities, and technical risk issues relevant to technical selection and decisions related to new project development and procurement
- Obtain reliability statistics on specific gas turbine models and provide analysis
- Prepare guidelines and specifications directly applicable to new project development, incorporating industry experience and related EPRI R&D
- Develop software designed to provide life-cycle cost perspective on O&M costs and risks
- Identify environmental and regulatory issues affecting new project planning

Accomplishments

EPRI’s New Combustion Turbine/Combined-Cycle Plant Design and Technology Selection program provides an objective, timely, life-cycle perspective on technology choice and improved plant design.

- Combustion Turbine Experience and Intelligence reports and project risk reports provide concise analyses of subjects of topical interest, including current and emerging CTCC designs and cycles, reliability issues, maintenance strategies, industry trends, and related market conditions.
- CTCC technology durability, design, and performance reports cover original equipment manufacturer (OEM) combustion turbine product lines, including design features, related risk concerns, and reliability, availability, maintainability-durability (RAM-D) experience. Component failure risk and durability information is based on in-depth studies of fleet-leading issues. All 50-Hz and 60-Hz models over 10 megawatts (MW) are covered, including advanced and upgraded mature engines. Procurement guidelines and specifications incorporate lessons learned from recent plant experience to support technical bid packages.
- Plant design, repowering, and environmental siting reports cover design features, risks, and operating experience of heat recovery steam generators, steam turbines, and electrical generators, as well as integration in an operationally flexible plant design. Emissions control equipment is described, and regulatory trends are monitored. Software provides model-specific O&M cost estimates. Design provisions are identified for plant operational flexibility and fuel variability appropriate for generation mission.

Current Year Activities

The program R&D for 2012 will focus on creating additional procurement guidelines and specifications and on gas turbine-based plant designs offering higher overall efficiency and lower emissions from startup to shutdown with improved cycling capability and low-load operation. Specific efforts will include:

- Following current subjects of interest in Combustion Turbine Experience and Intelligence reports
- Identifying new models, capabilities, and features in Gas Turbine Product Line Design Evolution and RAM-D Issues reports, and documenting emerging risk issues affecting durability
- Developing Engineering, Procurement, Construction (EPC)-style procurement specifications and guidelines that describe equipment and system design features for improved plant operability and fuel flexibility
- Enhancing maintenance life-cycle costing capability in Combustion Turbine/Combined-Cycle O&M Cost Analyzer software

Estimated 2012 Program Funding

$0.9M
Summary of Projects

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P80.001</td>
<td>Experience-Intelligence Reports and Project Risks</td>
<td>Project reports provide concise analyses of subjects of topical interest, including current and emerging CTCC designs and cycles, reliability/durability issues, maintenance strategies, industry trends, and related market conditions. Additional reports address specific project risk issues of interest to members.</td>
</tr>
<tr>
<td>P80.002</td>
<td>CT Technology: Durability, Design and Performance</td>
<td>Project reports cover CT product lines from major OEMs, including design features, related risk issues, and RAM-durability experience. All 50-Hz and 60Hz models over 10 MW are covered, including advanced and upgraded conventional engines.</td>
</tr>
<tr>
<td>P80.003</td>
<td>Plant Design, Repowering and Environmental Siting</td>
<td>Project reports cover design features and procurement specifications for commercially available combined-cycle plant equipment such as heat recovery steam generators (HRSG), gas and steam turbines, electrical generators, condensers, and cooling towers, and include best practices for integration in an operationally flexible plant design. The focus is on significant design improvements that differ from the previous plant build-out. Air emissions control and water usage equipment is described, and regulatory trends are monitored. Software tools provide rapid plant conceptual design and model-specific performance and cost estimate comparison. As equipment innovations occur, such as when new materials are introduced in the HRSG or new features are introduced in steam turbines to improve efficiency, existing reports and software are updated.</td>
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P80.001 Experience-Intelligence Reports and Project Risks (067359)

Key Research Question

Technical advances and issues surrounding combustion turbine (CT) and combined-cycle (CC) plants are major factors in new generation decisions, and the impact of those decisions will be felt for years to come. To optimize use of new technologies, plant managers and technical staff need objective, concise knowledge of innovation drivers and industry experience.

CT/CC plant owners and developers are challenged with multiple considerations and objectives in the plant design and selection of technology. A balanced approach to risk identification and cost allocation is essential in the technical development and financial strategy of any new plant project. For example, CT maintenance can cost two to three times the price of the original equipment over the project life. CT owners need to consider major maintenance costs during project development and recognize the technical maturity of particular turbine models. CT/CC project engineers must consider the many elements affecting plant operability and life-cycle costs. In addition, owners and developers need to understand price trends in fuel and electricity markets, and their impact on plant dispatch and profitability. Longer term, owners and operators need to consider the consequences of climate change legislation leading to carbon capture with CT/CC modifications in new plants and possibly retrofit applications.
Approach

EPRI collects and analyzes information about current and emerging CTCC designs and cycle configurations, and publishes the results in a series of concise reports supplemented by technical presentations. Topics covered include emerging technologies and processes that could affect future gas turbine and combined-cycle plant designs, commercially available technology comparisons, and projected trends in electricity and natural gas markets. Topics also include subjects such as best practices for fuel gas line cleaning, guidance on steam blows during commissioning, overviews of CT hot-section design features and durability issues, advanced clearance control techniques, emerging alternative parts suppliers, compressor dependability analyses, studies on low-NOx combustion instability studies, alternative fuel firing impacts, zero liquid discharge, carbon capture processes, air-cooled generator issues, and other topics as suggested by members.

In addition, project risk assessment reports help define and quantify risks associated with investment in new CT technologies. Guidance covers decisions about up-front maintenance strategies, such as self-managed maintenance or long-term contracts offered by the OEM or third parties. The INformation database of combustion TURbine engines (INTURB) for CT owners and operators provides a worldwide directory to facilitate contact with peers to discuss model- and configuration-specific concerns affecting procurement decisions. More in-depth special studies may examine detailed aspects of project risk such as the electricity market, natural gas supply, and the timing and impact of carbon capture and credits in the marketplace.

Impact

EPRI reports provide the background and analysis to evaluate various technology and configuration options, allowing program members to:

- Take full advantage of lessons learned in new and existing CTCC plants through concise, current information on new technology developments and issues affecting efficiency, emissions, durability, reliability, and plant operating flexibility to meet dispatch demands;
- Help mitigate technology and market risk for new CTCC project development through evaluation of alternative maintenance approaches and insights on natural gas and electricity markets; and
- Understand technology trends likely to be incorporated in the next generation of equipment/plant design

How to Apply Results

Reports serve as a resource for understanding major components of risk in project development and the use of insurance and maintenance contracts to mitigate a portion of the technical risk. Insights on model maturity and alternative parts suppliers support maintenance strategy planning. Other EPRI studies are employed to address project stakeholder concerns about equipment reliability risks and impacts from changing fuel and electricity market conditions. The INTURB CT owners’ directory can help identify other companies and contacts potentially able to provide valuable information and lessons learned from experience with equipment.

2012 Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>CT Experience and Intelligence Reports</strong>: Concise reports in article format provide analysis of subjects of topical interest, including current and emerging CTCC designs and cycles, reliability/durability issues, maintenance strategies, industry trends, and related market conditions. Reports, supplemented by technical presentations and webcasts, are compiled annually into a single report.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<th>Product Title &amp; Description</th>
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<tr>
<td>Project/Technical Risks Assessment: Reports address subjects of topical interest to members and update reports addressing project risk.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td>CT Experience and Intelligence Reports: Reports address approaches to managing risks and improving financial performance in gas turbine projects.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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</table>

P80.002 CT Technology: Durability, Design and Performance (104059)

Key Research Question

Understanding the design features of each gas turbine model and their relationship to overall capabilities and possible risks is a challenge. Project developers and electricity generation owners and operators need an in-depth perspective on technology design evolution, potential risks and benefits, as well as operation and maintenance (O&M) implications of new and upgraded model offerings for all major original equipment manufacturer (OEM) suppliers. When generating technologies are being selected, the mission requirements (baseload, daily start-stop, peaking, or electrical T&D support) influence the relative importance of the major competing goals of fuel efficiency, operational flexibility, and technical risk. Gas turbine manufacturers continue to add new and upgraded models to their combustion turbine (CT) product lines. New technology is improving performance, cycling capability, and durability of engines. Major innovations introduced by the OEMs to improve performance and correct deficiencies need to be evaluated and their risk attributes assessed.

Approach

This project periodically updates a multivolume series of reports, covering heavy-duty and aero-derivative engines over 10-MW capacity that are most frequently used in power generation applications. These reports summarize design characteristics of the turbine product lines manufactured by General Electric, Siemens (including Siemens-Westinghouse), Mitsubishi, Alstom, Pratt & Whitney, and Rolls-Royce. Smaller CTs produced by Solar, Hitachi, Kawasaki, and others used in distributed generation and cogeneration applications also are addressed. Each report includes a pedigree matrix, detailing design attributes in a standard format. Technical risk design features are identified, and relevant technical issues and experience are discussed. Reliability, availability, and maintainability (RAM) statistics are provided for selected models to further identify the overall model maturity and quantify RAM performance. Models of particular interest include advanced air- and steam-cooled F-, G-, and H/J-class machines, and engines suited for highly cyclic duty. The project seeks additional information about advanced models in design and field verification as opportunities arise.

Impact

- High-quality design assessments and in-service data support high-confidence technology selection and procurement decisions.
- Independently derived RAM statistics can be used in model evaluations.

How to Apply Results

Members can use these detailed reports to identify technical attributes and associated risks when planning generation additions with gas turbines. In the procurement process, the information is used to evaluate equipment and select appropriate technology.
### 2012 Products

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<th>Product Title &amp; Description</th>
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<tr>
<td><strong>General Electric Aero-Derivative CT Product Line - Design Evolution and RAM-D Issues:</strong> This report describes the design evolution, features, and performance of the LMS100, LM6000, and LM2500 gas turbine models, including recent upgrades. Current reliability and availability data is included. Technical issues affecting maintenance, durability, reliability, and life-cycle costs are reported. Maintenance intervals and activities are described. Existing sites are listed.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Small Combustion Turbines for Distributed Power Generation and Cogeneration (Solar, Kawasaki, Hitachi):</strong> This report describes the design evolution, features, and performance of the gas turbine models, generally in the range of 5-30 MW, manufactured by Solar, Kawasaki, Hitachi, MAN and others, including recent upgrades. Approaches to maintenance are described.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>General Electric Heavy-Duty CT Product Line - Design Evolution and RAM-D Issues:</strong> This report describes the design evolution, features, and performance of the GE 7FA/9FA/6FA, 7FB/9FB, 7H/9H, 7EA/9E, and 6B/6C heavy-duty gas turbine models, including recent upgrades. Current reliability and availability data are included. Technical issues impacting life-cycle costs affecting maintenance, durability, and reliability are reported. Existing sites are listed.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Mitsubishi CT Product Line - Design Evolution and RAM-D Issues:</strong> This report describes the design evolution, features, and performance of the MHI M501F/M701F, M501G/M701G, and M501D/M701D heavy-duty gas turbine models, including recent upgrades. The status of the M501J/M701J also will be covered. Current reliability and availability data are included. Technical issues impacting life-cycle costs affecting maintenance, durability, and reliability are reported. Existing sites are listed.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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### Future Year Products

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<tr>
<td><strong>Update to Heavy Duty CT Product Line Reports - Design Evolution and RAM-D Issues:</strong> Reports on large CTs by Siemens, Alstom, Mitsubishi, and General Electric are updated on a periodic basis to include the latest product offerings and capabilities, descriptions of durability and reliability issues, and site installations.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Update to Aero-Derivative CT Product Line Reports - Design Evolution and RAM-D Issues:</strong> Reports on aero-derivative CTs by Rolls-Royce, Pratt &amp; Whitney, and General Electric are updated on a periodic basis to include the latest product offerings and capabilities, description of durability and reliability issues, and site installations.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Update to Small CT Product Line Reports:</strong> Reports on small CTs by Solar, Kawasaki, Hitachi, and others will be updated on a periodic basis.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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P80.003 Plant Design, Repowering and Environmental Siting (067360)

Key Research Question

A plant design must satisfy multiple requirements, including increasingly stringent environmental regulations, high efficiency and reliability, and good operational flexibility. Features such as rapid startup and load change and low-load operation are highly valued in many markets, and some regions may require that plants have "carbon capture-ready" provisions. New regulations potentially could limit annual CO₂ production and further limit transient air emissions during startups. Water use and management is another growing environmental constraint. The drive for higher efficiency has led to innovations in the steam bottoming cycle, including operation at higher pressures and temperatures, requiring advanced materials in the heat recovery steam generator (HRSG) and steam turbine. OEMs are introducing plant configurations designed for certain missions. For instance, the FlexPlant 30 focuses on high efficiency with good startup times, whereas FlexPlant 10 focuses on rapid startup and reduced capital expenditures. Repowering an existing fossil steam site using natural gas-fired combustion turbines requires additional considerations. Plant developers need high-quality information and insight on best design practices and features. An integrated approach that includes evaluation of plant performance, capital costs, O&M costs, and market conditions on an overall life-cycle cost basis provides an opportunity for optimized plant design.

Approach

Reports focus on aspects of plant equipment and sub-systems that improve flexibility, durability, and efficiency. Procurement guidelines and specifications incorporate "lessons learned" from the previous build-out of combined-cycle plants. Software provides a framework for estimating operation and maintenance (O&M) costs based on specific CT model and operating duty on a life-cycle cost basis. Other software and studies provide detailed conceptual design and life-cycle cost analysis.

Impact

- Develop more competitive designs and improve equipment procurement decisions by using detailed information on combined-cycle design features, performance, and reliability trade-offs.
- Enhance operational flexibility by identifying and evaluating new plant design features.
- Assess air and water environmental control options.
- Quantify and compare plant conceptual designs and life-cycle costs based on user-defined scenarios.

How to Apply Results

Reports provide information for understanding equipment designs, making procurement decisions, and determining the most effective configurations to meet duty cycles and flexibility requirements. Equipment procurement guidelines can be used directly to support competitive bidding activities. Software quantifies the impact of operating scenarios on O&M costs and provides an overall life-cycle perspective.

2012 Products

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<th>Product Title &amp; Description</th>
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<tr>
<td>CO Oxidation Catalyst and Selective Catalytic Reduction of NOx: Design Best Practices and Procurement Guidelines: This report describes the best practices for design and procurement of CO oxidation and NOx reduction (SCR) catalysts.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Gas Turbine/Combined-Cycle Environmental Control Technology and Regulatory Issues Handbook: This report update includes information on the technical assessment of equipment for emissions controls and information on regulatory guidance for plant siting in the United States and select international regions. Typical regional permit levels for priority pollutants are included. Trends in new regulatory requirements are discussed.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<td><strong>Gas Turbine Equipment Selection Best Practices and Procurement Guidelines/Specifications:</strong> This report provides EPC-style procurement specifications and best practices guidelines for heavy-duty gas turbines commonly used in combined-cycle, simple-cycle, and cogeneration applications.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Repowering Studies and Assessments:</strong> This report will provide costs and performance data for repowering a fossil steam plant and summarize lessons learned in the reuse of existing steam turbines and other balance-of-plant equipment.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>CTCC O&amp;M Cost Analyzer:</strong> This software update is an Excel® spreadsheet-based software that estimates the O&amp;M costs for combined-cycle and simple-cycle plants for user-specified operating scenarios. CT model-specific maintenance costs are based on component replacement and repair costs, life estimates, and maintenance intervals. This product is shared with Program 79 (Combustion Turbine &amp; Combined Cycle O&amp;M).</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>SOAPP-CT Workstation, Initial Access:</strong> State-of-the-Art Power Plant (SOAPP) software provides capital costs and performance estimates for a life-cycle cost perspective on new combustion turbine/combined-cycle plant designs. New Program 80 funders obtain an initial one-year, two-user license to SOAPP-CT Workstation as part of a three-year Program 80 commitment. Future versions are accessed and supported through continuing supplemental project funding.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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**Future Year Products**

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<tr>
<td><strong>Cyclic Operation of Combined-Cycle Plants: Designs, Maintenance, Reliability and Cost Impacts:</strong> Updates to existing reports on &quot;lessons learned,&quot; repowering applications, and impact of cycling will be made periodically. A new version of the CTCC O&amp;M Cost Analyzer software will be released annually with updated costs and enhancements. New and updated procurement guidelines, including updates to the HRSG procurement specifications, will be issued based on new information and experience from members.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<td><strong>Lessons Learned in Startup and Commissioning of Simple-Cycle and Combined-Cycle Plants:</strong> Update to an existing report on &quot;lessons learned&quot; with additional content from recent plant startups.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Equipment Selection Best Practices and Procurement Guidelines/Specifications:</strong> New and updated procurement guidelines, including updates to the HRSG procurement specifications, will be issued based on new information and experience from members.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>CTCC O&amp;M Cost Analyzer:</strong> An updated version of the CTCC O&amp;M Cost Analyzer software will be released annually with updated costs and enhancements.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
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</table>
Supplemental Projects

Repowering Fossil Steam Plants with Combustion Turbines (072059)

Background, Objectives, and New Learnings

Many conventional fossil steam plants face uncertainty in future operation due to environmental regulations that would require significant upgrades to meet new emission standards. The capital expenditures required may be relatively high, particularly for moderately-sized to smaller-sized units firing coal or heavy oil. Older units may need significant boiler refurbishment to continue operation into the future. A reduction in carbon emissions also may be desired. One option commonly considered is conversion to a natural gas-fired combined-cycle configuration while maximizing reuse of existing equipment. This option is being more frequently implemented in the industry now that a period of secure availability of natural gas and relatively low fuel prices is projected. The objective of this project is to support the decisions involving the future of existing fossil steam plant assets in the generating fleet, particularly for those assets that require capital improvements and can no longer continue to operate at the status quo. In particular, owner/operators need to assess alternatives based on natural gas firing, such as repowering with combustion turbines in a combined-cycle configuration and either reusing the steam turbine(s) or installing a new combined-cycle unit at the existing plant site. This project adds the experience and lessons learned in repowering over the last decade to the background of EPRI experience in repowering to provide general guidance on repowering configurations, cost and performance attributes, and considerations unique to repowering existing fossil steam plants. These lessons then are applied to specific site repowering, leading to additional new learnings.

Project Approach and Summary

EPRI will conduct targeted evaluations of existing fossil plants to identify the technical and economic issues associated with converting conventional fossil steam units to combined-cycle operation. EPRI will use an extensive background from previous repowering studies and modeling tools such as the SOAPP Combustion Turbine/Combined-Cycle and SOAPP Repowering Workstations to provide an initial screening evaluation. After initial screening and focus, a detailed engineering evaluation of repowering the designated site will be performed. Information on completed repowering projects will be gathered and lessons learned from completed projects and studies will be compiled.

Benefits

Results from this project provide plant owners with a thorough assessment of costs to repower their sites with combustion turbines in a combined-cycle configuration, including reuse of existing equipment such as the steam turbine. Comparisons of performance and life-cycle costs with an all-new combined-cycle plant lead to better-informed decisions regarding repowering options. In addition, updated repowering guidelines summarize lessons learned from previous repowering projects that can be applied to other plants in the owner’s fleet.
Background, Objectives, and New Learnings

If legislation mandating a reduction in CO₂ production from fossil power plants is enacted, natural gas-fired combustion turbine/combined-cycle (CTCC) plants might also be required to capture and store carbon dioxide (CO₂). CTCC plants produce less than half the CO₂ per MWh of their pulverized coal (PC) counterparts, but they still are CO₂ emitters. As companies plan their future generation portfolios, there is growing interest in the feasibility and costs associated with applying large-scale CCS to CTCC plants and the impact on performance. That leads to questions about future emissions from CTCCs, including:

- Will highly dispatched CTCCs be challenged to reduce their CO₂ emissions level
- Will CTCC plants require retrofit in the future
- What preparations and pre-investments could be made to make the plant CO₂ capture-ready
- What are the corresponding cost, performance, and operational implications of retrofitting CCS

The objective of this project is to provide CTCC owners/operators with the information they need to understand the impact that a CCS retrofit would have on their plant performance and economics. This project provides new learning in the cost and performance of retrofitting post-combustion advanced amine solvent-based CCS to an existing or new CTCC plant. For a new planned plant, the project includes recommended provisions to enable a less-costly retrofit with CCS at a later date (i.e. “capture-ready”).

Project Approach and Summary

EPRI will examine CO₂ post-combustion capture (PCC) on a combustion turbine combined-cycle (CTCC) power plant for retrofit or planned application. Based on a planned or existing CTCC power plant designated by a host participant, the study will highlight the technical and economic issues associated with applying advanced amine post-combustion capture technology, one of the most developed processes available today.

EPRI has extensive background in evaluation of new and retrofit coal-fired applications of CCS and currently is conducting a technical and economic assessment study of post-combustion capture on natural gas-fired combined-cycle plants as a means to reduce CO₂ emissions from a typical F-class 2x1 CTCC plant. The current study will compare costs and performance for the generic new-build and retrofit cases and provide background for examining site-specific CCS applications.

For this proposed project, EPRI will examine post-combustion capture on a CTCC power plant for retrofit applications. It will include the knowledge gained from previous coal plant studies and current CTCC plant study, including process design improvements uniquely applicable to CTCC plants such as exhaust gas recirculation to improve CO₂ capture economics, and integration of the heat recovery steam generator (HRSG) with the post-combustion capture plant to minimize reduction in steam turbine output.

Benefits

Results from this project provide plant owners with a site-specific assessment of the costs to include carbon capture and compression in their designated site. Cost and performance for site retrofits then can be compared to generic differences between retrofit and new-build, leading to informed decisions regarding CCS options and risks. In addition, participants can gain insights into other host site configurations that can be applied to their own fleets.
Combined-Cycle Plant Design, Cost and Performance Software (057519)

Background, Objectives, and New Learnings

Companies in the electric utility industry increasingly find it difficult to allocate sufficient resources to study the latest developments, evaluate alternatives, and optimize solutions for new plants. The impact of different scenarios on plant cost and performance, and consequently on the most cost-efficient plant design, often is neglected. Competitive pressures have driven engineering towards more standardized designs, which offer cost/performance for “average” applications but often are sub-optimal for any specific application. State-of-the-Art Power Plant (SOAPP®) software products address these issues.

Starting with user-defined inputs and guidance from initial default values, the SOAPP Workstation validates inputs, sizes and costs equipment, and performs detailed performance and economic analyses of the resulting conceptual design. Outputs include plant performance summaries, equipment lists and sizing, capital costs and O&M costs, diagrams and drawings. Financial outputs include capital outlay schedules, capacity and energy payments, pro forma income and cash flow statements, and internal rates of return.

Ongoing support and development are key to providing an up-to-date software tool for the user and incorporating state-of-the-art information. The objectives of this supplemental project are to:

- Provide scientific tools for analysis of performance, design and profitability of power projects in a site-specific context to enable a life-cycle cost perspective on power plant projects;
- Provide development of the SOAPP-CT Workstation software for use by project participants; and
- Provide technology transfer and strategic decision support for developing new electric power generating plants

The SOAPP software enables the evaluation of alternatives through the scientific modeling and simulation of power plants, and generates substantial new learning by using feasible scientific and technical solutions for the problems of identifying and communicating state-of-the-art complex technical relationships. Accurate planning and optimized projects for minimum electricity cost, lessened environmental impact and maximum reliability, are made possible through the funders’ use of the software for improved productivity of their technology assessment efforts and ability to evaluate potentially beneficial alternatives. Major technology trends related to new gas turbines and steam turbines underlie SOAPP software development. The SOAPP-CT Workstation software captures the performance and costs of these new state-of-the-art innovations.

Project Approach and Summary

The project develops new versions of the SOAPP-CT Workstation to incorporate new design characteristics of combined-cycle plants, up-to-date performance and cost information, and additional enhancements, as well as supports funders through updates to the SOAPP website and preparation of training materials and communications to current and prospective funders.

Benefits

The fully-integrated SOAPP-CT Workstation enables users to quickly develop a detailed plant conceptual design and then evaluate the impact of different equipment choices and design criteria on plant design, performance, emissions, and costs. This allows business and technical decisions to be made in concert, encouraging development of project-specific power plant designs with the lowest life-cycle costs. The CT Technology Modules summarize and compare viable, commercially available state-of-the-art technologies and can be used for general technology transfer and training. The Windows-based SOAPP software has an extensive on-line help function. The software and user manual are distributed on CD-ROM for installation on individual PCs.

SOAPP helps to optimize the numerous decisions tied to a typical $200 to $500 million combined-cycle project. Use of the SOAPP products can lead to better-informed decisions regarding construction of new power plants and the upgrading of existing plants, reducing the cost of electricity and environmental impact. The SOAPP-CT
Workstation reduces a task that otherwise could take several man-months of effort to less than an hour, resulting in productivity savings. More importantly, it enables users to evaluate many more alternatives than they could afford without SOAPP and thus achieve an optimal design. Substantial benefits can be realized when the use of the SOAPP-CT Workstation results in the choice of technologies that produce a different, more economical plant design.
Heat Recovery Steam Generator (HRSG) Dependability - Program 88

Program Overview

Program Description

Heat recovery steam generators (HRSGs) pose a unique set of operational challenges, due in part to their rapid startup capabilities and high operating efficiencies. Preventing HRSG tube failures (HTFs) is a priority, but complex failure paths, which are influenced by cycle chemistry or thermal transients, are difficult to understand and mitigate. Limited access and other complexities make inspection and repair of HRSGs very difficult.

The Electric Power Research Institute’s (EPRI’s) Heat Recovery Steam Generator Dependability program (Program 88) provides a complete set of technical tools to improve the performance and reliability of combined-cycle HRSGs.

Research Value

Projects include unit-specific and pressure-circuit-specific chemical treatment methods and limits, optimal approaches to preventing HRSG tube failure, and methods for life assessment, nondestructive evaluation (NDE) options, welding, and other repair methods. Using the R&D from this program, members can:

- Achieve tube failure rates consistent with their risk tolerance and financial models
- Increase reliability through better understanding of HRSG thermal transients
- Increase understanding and control of flow-accelerated corrosion (FAC) through an initial predictive code and other technologies
- Optimize HRSG operational and shutdown chemistry through better understanding of the chemistry cycle
- Identify and correct cycling and thermal transient problems through chemistry cycle guidelines and methods
- Optimize HRSG inspection and repair by using new hardware, NDE guidelines, and techniques for improving access

Approach

Operator guidelines help monitor, identify, and minimize the effects of shutdown, startup, and thermal transients on fatigue life, while a diagnostic expert system helps control and maintain optimal chemistry. Regional workshops covering HRSG tube failure, cycle chemistry, inspection, and FAC effectively transfer the knowledge gained through this program.

- HRSG cycle chemistry R&D recently completed a two-year study of an assessment technology for deposition in high-pressure (HP) evaporators that will involve circulation considerations. Additional work will summarize the potential for using organics in HRSGs.
- HRSG tube failures and life-assessment research is continuing to develop a comprehensive methodology to assess cycling capability, including optimizing startup in terms of thermal transients. The program also continues to document case studies and develop life-assessment tools and methodologies, and complete a model for two-phase FAC to assist in proactive FAC control.
- HRSG NDE and repair R&D includes developing and demonstrating external inspection techniques with remote capability, developing final equipment for HRSG tube elbow replacement near headers, and assessing an internal coating technology to provide protection against FAC.
- EPRI workshops for HRSG dependability are offered regionally to members of the HRSG Tube Failure Reduction/Cycle Chemistry Improvement Program and FAC and NDE programs.
Accomplishments
EPRI's thermal transient and cycle chemistry guidelines provide quantitative, specific suggestions for obtaining the best possible performance from existing HRSGs. The guidelines also provide guidance applicable to new units for appropriate design of pressure parts.

- EPRI has developed comprehensive guidelines on cycle chemistry for all HRSGs, including shutdown/startup chemistry and chemical cleaning.
- EPRI has developed a complete approach to identifying reasons for thermal transients, as well as related analytical tools.
- EPRI has developed a troubleshooting guide that, through a group of 57 questions, can help identify whether and which underlying causes (or both) of thermal transients are present in the operating practices or in the design of the HRSG.
- Unique repair technology has been developed, as well as a revision to the interim NDE guidelines, to include case studies of visual techniques and technology transfer materials.

Current Year Activities
Program R&D for 2012 will continue to focus on thermal transients and chemistry directly responsible for damage to HRSG pressure parts. Specific efforts will include:

- Exploration of technologies to address HRSG Tube Failures (HTFs)
- Technology to assess control of steamside deposition
- Case studies and development of HRSG life assessment tools and methodologies
- Further development and demonstration of remote capabilities for external inspection techniques
- Exploration of technology for organics treatment

Estimated 2012 Program Funding
$1.5M

Program Manager
Bill Carson, 704-595-2698, bcarson@epri.com

Summary of Projects

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P88.001</td>
<td>HRSG Cycle Chemistry</td>
<td>This project R&amp;D helps reduce HRSG tube failures by providing guidelines to improve cycle chemistry through management of key failure mechanisms.</td>
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<tr>
<td>P88.002</td>
<td>HRSG Tube Failures and Life Assessment</td>
<td>This project provides in-depth investigations and guidelines, addressing high-risk component failure root-cause mechanisms. Corrective solutions and damage mitigation techniques are developed, evaluated, and demonstrated.</td>
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<tr>
<td>P88.003</td>
<td>HRSG NDE and Repair</td>
<td>This project develops technologies and techniques to improve internal and external HRSG repairs.</td>
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<tr>
<td>P88.004</td>
<td>EPRI Workshops for HRSG Dependability</td>
<td>Regional workshops provide information and lessons learned in HRSG availability to utility operators, chemistry staff, and maintenance staff.</td>
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P88.001 HRSG Cycle Chemistry (051612)

Key Research Question

HRSG tube failures are influenced and controlled by cycle chemistry, which consists of flow-accelerated corrosion (FAC), underdeposit corrosion (mainly hydrogen damage), corrosion fatigue, and pitting. EPRI’s suite of HRSG cycle chemistry guidelines is designed to manage all of these failure mechanisms.

Approach

Reliable operation of combined-cycle/HRSG units requires careful consideration of cycle chemistry. EPRI already has developed guidelines for complete cycle chemistry, shutdown and lay-up, and chemical cleaning. The next steps will address the chemistry during startups and the deposition process in high-pressure evaporator tubing. This effort will link closely with the nondestructive measurement of internal deposits in P88.003.

Impact

- Significant reduction and improved management of chemistry-related generation losses in HRSGs
- Improved unit availability and reduced O&M costs through prevention of chemically influenced HTF
- Control of corrosion damage and deposition problems in HRSGs and steam turbines of combined-cycle plants

How to Apply Results

Members may benchmark their chemistry programs independently or in collaboration with EPRI staff to identify areas of deficiency and determine approximate costs. The content of the chemistry guidelines can then be used to identify specific actions needed to address those deficiencies in a manner consistent with individual unit characteristics. For example, the chemistry guidelines can be consulted to verify proper selection and optimization of HRSG water chemistry used in individual fossil units. The benchmarking process should be repeated periodically as a means of checking the overall effect of improvements implemented. That way, success can be gauged by measuring progress against a rigorous set of performance metrics consistent with the EPRI guidelines.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tr>
<td>Deposition Processes &amp; Mechanisms in Heat Recovery Steam Generators (HRSGs): The research for this project is anticipated to identify mechanisms contributing to the deposit formation and morphology. It models the deposit growth, maturation, and accumulation of contaminants leading to under-deposit damage, and confirms deposition and mechanics in a simulated environment test autoclave with heated electrochemical corrosion potential (ECP) probe. This project is conducted in conjunction with Program 64 (Boiler and Turbine Steam and Cycle Chemistry).</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Additional Research Into 2-Phase FAC: This project uses laboratory simulation to evaluate methods for mitigating two-phase FAC such as steamside of feedwater heaters and drain lines and HRSG low-pressure (LP) economizer evaporator tubes. This project is conducted in conjunction with Program 64.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>In-Situ Monitoring: The purpose of the project is to evaluate linear polarization resistance (LPR) corrosion probes as part of alternative layup techniques. This project is conducted in conjunction with Program 64.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P88.002 HRSG Tube Failures and Life Assessment (051614)

Key Research Question

HRSG tube failures are caused by flow-accelerated corrosion; under-deposit corrosion in evaporator circuits; corrosion and thermal fatigue in economizer, superheater, and reheater circuits; and creep fatigue in superheaters and reheaters. Over the last six years, work within the program has addressed the known fatigue-initiated and chemically influenced failures. There is a growing concern, however, that HRSG components will approach end-of-life sooner than expected or seen in conventional boilers. As a result, HRSG owners and operators need to be able to quickly and economically assess the health of major HRSG components.

Approach

The program will begin development of a predictive methodology for HRSG component life assessment. Work will continue on development and validation of research on HRSG pressure-part, thermal transient limits and mitigation, and research will be able to factor in how the operation of the unit affects the life calculation, inspections, and testing requirements.

Impact

- Achieve significant improvement in HRSG availability
- Reduce operations and maintenance cost through reduced HRSG component failure

How to Apply Results

The end-of-life methodology should help HRSG owners determine when inspections should occur, what types of inspection/testing are needed, and how to plan for replacement or repairs. The approach will take into account the previous years' work on thermal transient, cycling, and design issues.

2012 Products

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<tr>
<td>Development of HRSG Dew-Point Deposition on Back-End Pre-Heater and Economizer Tubing Guideline: Back-end corrosion continues to be a nuisance to the HRSG operator. It has not yet been determined to cause concern, but there is a growing interest in how it affects the performance and what is needed to clean the tubing. This is a follow-up to the work that will be done in 2011 to clean the deposits once formed. The 2012 project will study the long-term effects of the deposits and, if needed, eliminate the formation of the deposits on the tubing. A possible approach could be to coat the tubes with ceramic and examine how effective the coating is for deposit shedding.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Development of HRSG Component Life-Assessment Document: This project is to develop life-management strategies for HRSGs. This will include piping and the specific challenges related to cycling and high-temperature damage (creep). It also looks to provide templates for performing key maintenance activities using either in-house staff or contractors to increase overall awareness of issues and solutions.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>&quot;Used&quot; HRSG Purchase Specification: Many companies are looking for “on the ground” HRSGs to supplement their generation portfolios. This oftentimes is an economical alternative to the difficult and time-consuming development, permitting, and construction for a new build. This report will provide the questions to ask when performing due diligence, utilizing the many reports, projects Program 88 has prepared.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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HRSG Material Selection Guideline Update: The existing guidelines provide an excellent overview of a broad range of HRSG components, but offer limited information on the detailed materials selection process for specific HRSG components, especially for new HRSG designs with steam temperatures approaching 1100 degrees F (590 degrees C). To stay current with the anticipated new advanced materials and operating ranges, this project will update the existing materials guideline.

12/31/12 Technical Update

Guideline for Converting Baseload-Designed HRSG Into Cycling Service: Most HRSG units are operating outside their design. It has been shown that cycling service from economic and environmental issues can expose the baseload-designed units to new damage, affecting the availability of the unit. This project would examine the cost and projects needed to convert a unit from baseload to cycling service.

12/31/12 Technical Report

P88.003 HRSG NDE and Repair (055580)

Key Research Question

Inspection, nondestructive evaluation, and repair of HRSG tubes and tube/header attachments are very difficult due to restricted access. EPRI has developed a series of techniques and technologies to conduct repairs from the internal surfaces. NDE developments have been similarly directed to provide internal examination techniques as well as reduce thermal transients and thermal fatigue damage.

Approach

This project will continue to explore the tube elbow replacement device, described in a 2008 EPRI technical report. Work also will continue to develop an external delivery device that can be used to provide welding, repair, sampling, and NDE on HRSG pressure components. The NDE project will continue to develop and demonstrate external examination techniques to address damage.

Impact

- Enhance unit availability
- Reduce tube/header examination and repair times
- Experience fewer HTFs
- Benefit from validation of damage assessment and models
How to Apply Results

The NDE Guidelines provide members with tools and guidelines on the performance of nondestructive evaluation of HRSGs, so they know what types of NDE procedures to perform and where to perform them. These tools and guidelines are especially useful during HRSG tube failures and outages, because they provide comprehensive information on where HRSG failures occur, which damage mechanism is operative on various components, how to examine the components for damage, and how to establish subsequent re-inspection intervals. The internal examination technique and delivery device developed through this program most likely will be commercialized through a third-party vendor, increasing opportunities for members to deploy the device.

2012 Products

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<tr>
<td><strong>Continued Development of Snake Robot Technology:</strong> This project will continue the work with Carnegie Mellon University on developing the snake robot technology for inspections in hard-to-reach areas and on attaching additional tooling to the robot.</td>
<td>12/31/12</td>
<td>Hardware</td>
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<tr>
<td><strong>Southwest Research Institute Tube-to-Header Flexible Eddy Current Probe that can be Attached to a Robotic Delivery System:</strong> This project is to attach the technology already available to the industry to a robotic delivery system. Due to the tight tubing arrangement, a remote or robotic delivery system would benefit the industry in proactively identifying internal cracking in areas that currently are inaccessible.</td>
<td>12/31/12</td>
<td>Hardware</td>
</tr>
<tr>
<td><strong>Enhanced Development of NDE System for Inspection of Finned Tubing:</strong> Although very few failures have been experienced within the finned tube area, it is anticipated that that this problem will grow. Very few tube samples have been taken, due to the complexity and tight arrangement of the HRSG tubing. If corrosion is experienced, there is significant wall reduction in the HRSG tubing, and early detection of wall loss is necessary to achieve maximum availability. This project will assist operators of HRSG in early detection of tube wall loss.</td>
<td>12/31/12</td>
<td>Hardware</td>
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P88.004 EPRI Workshops for HRSG Dependability (051615)

Key Research Question

EPRI surveys indicate that focused workshops offer a significant benefit in HRSG availability to utility operators, chemistry staff, and maintenance staff. Improvements can be realized by understanding the influences of inadequate cycle chemistry, unidentified severe thermal transients, and effective inspections. Each of these areas has been addressed in other projects within the HRSG program.

Approach

This project offers workshops conducted regionally for key personnel involved in the design, operation and maintenance, and NDE of HRSGs. Workshops utilize materials resourced and updated from other program projects. Workshop modules demonstrate ways that HRSG operators can proactively identify severe thermal transients and optimize cycle chemistry for each pressure cycle.

Impact

- Improve unit availability significantly
- Reduce operations and maintenance costs via workshops that increase member awareness of the thermal and chemistry factors contributing to HRSG tube failure as well as effective inspection and repair techniques
How to Apply Results

Attendance at HRSG workshops increases members’ knowledge of research results that can meet their specific plant needs. Workshop information can be used to optimize the cycle chemistry in each pressure cycle, establish a monitoring program, or refine an existing program. Members can work with EPRI staff to identify which sections of an HRSG should be monitored and inspected with NDE techniques, and which available repair methods can be applied to mitigate damage.
Combustion Performance and Emissions Control - Program 71

Program Overview

Program Description

The three general issues addressed in the P71 program include: 1) combustion and fuels impacts on boiler tube life; 2) impacts of combustion modifications and fuel quality on emissions; and 3) plant heat rate.

Forced outages due to fireside corrosion, circumferential cracking, and deposition of ash (e.g., slagging and fouling), which in many cases are significantly exacerbated by low-NOx operation, remain a costly issue. As coal plants shift to lower-cost/lower-quality coals — in many instances, to take advantage of recently installed flue gas desulfurization systems — and as coal plants increase the level of combustion staging (needed to comply with more stringent NOx regulations), innovative and cost-effective solutions will be needed to maintain boiler tube reliability.

As the most cost-effective means of reducing emissions from coal-fired power plants, combustion considerations should be viewed as the first step in any compliance strategy. Recent regulations (the Clean Air Transport Rule, or CATR, and maximum achievable control technology, or MACT) will make an even stronger case to deploy cost-effective combustion-based controls for reduction of nitrogen oxides (NOx), CO, SO3, mercury and other hazardous air pollutants (HAPs), and unburned carbon.

Rising fuel costs will increase the need to improve plant heat rate and combustion performance. In addition to fuel costs, heat rate improvements bear a direct relationship on tonnage releases of all pollutants, including CO2.

For all of these issues, understanding of fuel quality considerations, accurate measurement and control of coal and air flow to individual burners, and improved performance of pulverizers, burners, and other critical combustion- and performance-related hardware is imperative. The Electric Power Research Institute’s (EPRI's) Combustion Performance and NOx Control program (Program 71) provides the knowledge and resources needed to develop, demonstrate, and apply cost-effective combustion-based solutions to resolve these and other combustion- and fuels-related issues.

Research Value

The Combustion Performance and NOx Control program focuses on a holistic approach to combustion and fuel quality impacts, including emissions, performance, and reliability.

- Avoiding a single forced outage due to fireside corrosion, circumferential cracking, or slagging and fouling can save more than $1 million per unit.
- Heat rate improvements yield significant savings in fuel costs and are by far the lowest-cost and only commercially available method of reducing CO2 at this point in time. A 1% heat rate improvement on a single 500-MW base-loaded unit can save as much as $1M/year in fuel costs alone, and can reduce CO2 emissions by approximately 40,000 tons per year.
- Enhancing NOx reductions with cost-effective combustion modifications, even on units equipped with SCR systems, may yield significant revenues in an anticipated NOx credit market.

Approach

Projects in three distinct groups help mitigate fireside corrosion and waterwall wastage in low-NOx systems; develop and demonstrate cost-effective emissions control through combustion modifications and assessments of emerging technologies; and optimize heat rate.
Mitigation of the impacts of combustion and fuel quality on boiler tube longevity, including waterwall wastage, circumferential cracking, and slagging and fouling, will significantly reduce the number of costly forced outages. Participation in EPRI’s Combustion and Fuels Impacts Interest Group (CFIG) helps members identify applicable projects, disseminate results, and share best practices regarding all aspects of the impacts of combustion and fuel quality on boiler tube life.

Members also receive assistance in analysis of tube wastage, circumferential cracking, and ash deposition problems, fuel quality and blend ratio impacts, and selection of protective coating alternatives. State-of-the-art modeling tools are used to develop guidelines to assess waterwall wastage based on coal quality, furnace design, and operability.

Combustion modifications may provide the most cost-effective first step in controlling a number of pollutants in addition to NOx. Development of guidelines and best practices, data from full-scale demonstrations, and assessments of emerging technologies provide important information to make informed decisions. Value to members may include the ability to capitalize on the anticipated NOx credit market and avoidance of higher-cost emissions controls.

Solutions for fuel quality issues enhance fuel flexibility, unit reliability, and combustion performance. Members can achieve substantial cost savings through improved boiler performance, regain lost capacity, and benefit from increased flexibility in fuel sourcing.

Coal and air flow measurement and control R&D investigates solutions for controlling the distribution of air and pulverized coal flow to individual burners. Members can use project findings and deliverables to resolve coal and combustion air flow distribution issues at their coal-fired facilities, resulting in lower emissions, reduced fuel costs, improved boiler operation, and minimized operability issues such as fireside corrosion and unburned carbon in ash.

Improved heat rate can reduce the cost of operation through fuel savings and increased availability. In addition, improving heat rate is by far the most cost-effective method and the only "ready now" method of reducing CO2 emissions, as well as reducing all other pollutants on a tonnage basis. Members can use project deliverables to assess and implement tools and technologies to improve plant performance and lower heat rate and CO2 emissions. Participants in full-scale demonstrations, available to all program members, will gain firsthand experience with issues and solutions.

Accomplishments

For more than two decades, EPRI has led the power industry in developing, advancing, and demonstrating cost-effective NOx and other emissions control technologies and best operating practices for achieving compliance at minimal cost and maximum reliability. More recently, EPRI has led the industry in identifying, quantifying, and seeking cost-effective solutions to operability and performance issues associated with low-emissions operation, such as fireside corrosion, circumferential cracking, heat rate, and fuel quality impacts. Accomplishments include:

- Development of the Vista model to assess the impacts of coal quality on the total cost of operation.
- Development of advanced models to predict and assess methods of combating fireside corrosion consequential to implementation of low-NOx systems
- Deployment of the Coal Flow Loop (CFL), a full-scale facility to develop and evaluate methods of measuring and controlling coal flow from pulverizers to individual burners
- The Flame Doctor™ Flame Diagnostics System, an advanced burner diagnostics tool to improve performance and reduce emissions on wall-fired and cyclone boilers
- Innovative, cost-effective technologies for combustion NOx controls, such as advanced staging methods
- Slagging and fouling guidelines that offer quantifiable methods of identification and mitigation methods for ash deposition issues
- Site evaluations for production cost optimization and boiler air in-leakage reduction, which provided participating companies the framework to apply these methods to improve plant performance at other units across their fleets
- Sponsorship of workshops, conferences, and webcasts in which funders and other key industry participants can share ideas and best practices, and outline needed solutions.
Current Year Activities

The program R&D for 2012 will continue to focus on a holistic approach to combustion optimization, including combustion and fuel quality-related impacts on emissions, performance, and operability. Specific efforts will include:

- Cost-effective solutions for the impacts of low-NOx combustion and fuel quality on boiler tube life, such as fireside corrosion, circumferential cracking, and ash deposition.
- Advanced sensors and feedback loops to quantify gaseous species distributions (i.e., O₂ and CO) and enable corrective actions that optimize fuel/air distribution in the boiler.
- Holistic impacts of combustion modifications on all pollutants, including mercury speciation for downstream capture (with Program 75).
- Predictive tools to assess the impacts of coal quality, boiler design, and operation on fireside corrosion, circumferential cracking, and slagging and fouling.
- Guidelines, demonstrations, and conferences and workshops for improved heat rate for lower fuel costs and as a first step in minimizing CO₂.
- Assessments of coal flow control devices and methods (at EPRI’s Coal Flow Loop and at full scale in host plants) for coal/air balancing, which are found to have a first-order impact on plant emissions, performance, and operability.

Estimated 2012 Program Funding

$3.5M

Program Manager

Anthony Facchiano, 650-855-2494, afacchia@epri.com

Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P71.001</td>
<td>Combustion and Fuel Impacts on Boiler Tube Longevity</td>
<td>This project develops assessment and mitigation strategies for combustion-related boiler tube failures due to low-NOₓ operation, such as fireside corrosion and circumferential cracking, based on coal quality, boiler design, and operational considerations.</td>
</tr>
<tr>
<td>P71.002</td>
<td>Cost-Effective Emissions Control via Combustion Modifications</td>
<td>This project develops guidelines and best practices that enable implementation of cost-effective combustion modifications to minimize NOₓ levels and other pollutants such as mercury and unburned carbon, as well as optimize combustion performance.</td>
</tr>
<tr>
<td>P71.003</td>
<td>Heat Rate and Cost Optimization</td>
<td>This project develops and demonstrates a variety of deliverables and services to promote optimal heat rate and minimal cost of operations, including economic evaluation of fuel quality impacts on heat rate; the effects of increased cycling and load following operation; best practices for plant performance monitoring and improvement, and conferences and workshops focused on key topics prioritized by participants.</td>
</tr>
</tbody>
</table>
P71.001 Combustion and Fuel Impacts on Boiler Tube Longevity (070555)

Key Research Question

Boiler system owners and operators need cost-effective solutions to reduce the number of costly forced outages stemming from fireside corrosion, circumferential cracking, slagging and fouling, and other boiler tube impacts consequential to low-NOₓ operation and fuel quality considerations. Low-NOₓ operation often results in fireside corrosion and waterwall wastage-related boiler tube failures, and although weld overlays may alleviate this situation in many instances, associated problems with circumferential cracking may be exacerbated. Addressing the impacts of low-NOₓ combustion and fuel quality on boiler tube longevity is critical to maintaining and improving unit reliability and performance.

Approach

EPRI's multifaceted approach to understanding and resolving the costly consequences of accelerated fireside corrosion, circumferential cracking, slagging, fouling, and other impacts of low-NOₓ combustion and fuel quality on boiler tube longevity will include:

- Role of fuel properties such as chlorine, sulfur, ash compounds, and fuel blend ratios
- Effects of boiler design and various modes of low NOₓ operation; and
- Operational- and materials-based solutions and issues

The advanced Corrosion Predictor Model, the Advanced Slagging Predictor, and other state-of-the-art modeling tools will be used to develop guidelines to assess circumferential cracking, waterwall wastage, slagging and fouling, and other operational and reliability issues based on coal quality, furnace design, and operability. Cost-effective solutions will be developed and demonstrated. The issue of circumferential cracking, exacerbated both by low-NOₓ operation and utilization of weld overlays, will be addressed, and alternative material solutions such as thermal spray and ceramic coatings will be assessed.

Impact

- Reduce the number of costly forced outages due to fireside corrosion and circumferential-cracking-related boiler tube failures.
- Reduce O&M costs by selecting effective protective coatings and weld overlays, as well as by taking into account coal quality considerations.
- Participate in EPRI's Combustion and Fuels Impacts Interest Group (CFIG), which helps members identify specific projects, disseminate results, and share best practices through annual meetings and periodic webcasts.
- Receive technical assistance in all aspects of circumferential cracking, fireside corrosion, and slagging and fouling-related issues, including analysis of wastage problems, weld overlay cracking, fuel quality and blend ratio impacts, and appropriate selection of protective coating alternatives.

How to Apply Results

Plant personnel responsible for boiler systems reliability and performance can employ project findings and deliverables to mitigate accelerated fireside corrosion, circumferential cracking, and slagging and fouling impacts on reliability. Mitigation methods may be applied to boiler operation (especially combustion considerations), material-based coatings such as weld overlays and thermal sprays, and fuel quality.
## 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Thermal Spray and Ceramic Coating State of Knowledge Update:</strong> Options for thermal spray and ceramic coatings will be assessed, with performance data provided on various options. The latest findings from field demonstrations will be incorporated.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Combustion Guidelines for Maximum Boiler Tube Life:</strong> Update and dissemination of operational guidelines, which include all combustion and fuels aspects of boiler operation affecting boiler tube life. Dissemination may include seminars to plant engineering and O&amp;M staffs.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Impacts of Alternative Fuels and Blends:</strong> Continuation of the work initiated in 2011. The impacts of alternative fuels and blends — including opportunity fuels and biomass — as well as the impacts of higher sulfur and chlorine levels will be assessed for consequences regarding corrosion, circumferential cracking, slagging and fouling, and other operability issues.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Coating Corrosion Fatigue/Cracking Lab Testing:</strong> Lab tests will continue to assess the impacts of corrosion fatigue and cracking on a variety of weld overlays, thermal sprays, and ceramic coatings, and deposits (e.g., reducing sulfur and chlorine species). Tests will investigate the impacts of temperature, surface roughness and defects, and new alloys, and assess crack initiation mechanisms. Advanced coating materials will be assessed.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Databases and Correlations:</strong> This database will continue to compile experiences with weld overlays, spray coatings, and bare tubes, including data analysis and mitigation steps taken by different utilities. Information from the database may be used to assess when circumferential cracking, hardening, and fatigue of weld is probable based on data from various plants. The database also will include experiences and installation practices for a variety of coating applications in a power boiler to mitigate corrosion and minimize slagging.</td>
<td>12/31/12</td>
<td>Assembled Package</td>
</tr>
<tr>
<td><strong>Annual Workshop and Webcasts on Specific Topics:</strong> An annual two-day meeting will include technical presentations on all EPRI fireside corrosion, circumferential cracking, and ash deposition-related activities, as well as member presentations and group discussions of case studies and issues. In addition, webcasts will be conducted on specific topics pertaining to the impacts of combustion and fuel quality on boiler tube longevity (e.g., circumferential cracking, fireside corrosion, and ash deposition).</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Fuel Quality Impacts on Corrosion and Wall Deposition:</strong> Boiler tube corrosion and slagging estimates will be provided as a function of fuel and ash quality and changes in fuel blend ratios. Corrosion predictions will be made using EPRI’s Thermo-Chemical Equilibrium Simple Predictor, along with other advanced slagging predictor tools.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Circumferential Cracking Prediction Tool:</strong> The project will initiate development of a spreadsheet-type tool to predict circumferential cracking, based on empirical data available from previously run lab tests and field applications. Similar to corrosion and slagging predictions tools, the circumferential cracking model will estimate impacts as a function of fuel quality and unit design.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>State of Knowledge of Fuel Quality Analysis Technologies:</strong> This project will focus on establishing the status of advanced and cost-effective laboratory and in-situ fuel quality systems. The objective is to define technologies that have correlated real-time fuel quality information with boiler performance and potential operation adjustments.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
P71.002 Cost-Effective Emissions Control via Combustion Modifications (050311)

Key Research Question

Combustion modifications are the most cost-effective first-line approach to reducing emissions — primarily NOx but also mercury and other hazardous air pollutants (HAPs), sulfur oxide (SOx), CO, and unburned carbon in ash/loss on ignition (LOI). This project will assess emissions reductions achievable with combustion modifications by considering fuel quality, boiler design, boiler operating modes, and other site-specific factors. The consequences of candidate combustion modifications on boiler performance, reliability, and other pollutants, and steps that can be taken to minimize these impacts, also will be addressed. This project also will evaluate the performance of key combustion-related hardware components, such as pulverizers, along with application of advanced sensors and monitors. The impacts of coal and combustion air distribution, along with devices to measure and control coal and combustion air flow, will be assessed.

Approach

This project will develop guidelines and best practices that enable members to employ cost-effective combustion modifications to the fullest extent for the purpose of reducing emissions and improving reliability and performance. Activities will include:

- Case studies documenting combustion factors influencing achievable NOx emissions
- Methods of minimizing CO and LOI without sacrifice to NOx levels or heat rate.
- Impacts of combustion modifications on mercury capture
- Methods of improving mill performance such as throughput, particle size, and distribution, which will, in turn, improve combustion performance and emissions
- Demonstration of continuous in-furnace and economizer gaseous species monitoring devices
- Cost and performance optimization of combustion-based NOx controls when used in combination with selective catalytic reduction (SCR)
- Objective assessments of emerging in-furnace NOx control technologies (including field data)
- Assessments of devices to measure and control coal and air flow, and impacts of burner-to-burner fuel and air distribution on emissions and performance

Impact

- Avoid higher-cost NOx controls required to comply with present and anticipated regulations, and capitalize on NOx credit markets when economically justified.
- Access performance data and third-party assessments of emerging combustion-based NOx control options to help select the most appropriate technologies.
- Apply results of the development and demonstration of the impacts of combustion modifications on control of CO, unburned carbon, mercury, sulfur trioxide (SO3), and other pollutants.

How to Apply Results

Utility staff involved in economic assessments, applicability issues, and considerations of combustion modification-related technologies can apply project information on emerging technologies maintained in real time on the EPRI website. In addition, participants in full-scale demonstrations of advanced technologies, which are available to all project members, will gain firsthand experience with technology performance and learn about the advantages and shortcomings of emerging options compared to more established approaches.
## 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Evaluation of Boiler Tuning Methods to Reduce CO Emissions and Improve Boiler Performance</strong></td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>This project will evaluate combustion optimization methodologies for their ability to adjust combustion controls in order to reduce and minimize CO emissions on a continuous basis during full-load operation, load cycling, as well as in response to changes in coal supply.</td>
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<tr>
<td><strong>Boiler/SCR Performance Optimization Methodology</strong></td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Based on case study examples, a methodology will be developed to examine the tradeoffs between combustion and SCR NOx reductions, with the goal of identification of boiler exit/SCR inlet NOx levels that result in minimum overall costs, considering boiler and SCR operability issues such as corrosion, efficiency, unburned carbon, and reagent costs. It also may include a review of achievable boiler exit NOx levels as a function of boiler design and fuel type, using EPA-reported emissions and internal databases and member input regarding unit design information, installed burners, and coal fuel characteristics for boilers surveyed. This project will be done in coordination with Program 73 (Post-Combustion NOx Control).</td>
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<tr>
<td><strong>Holistic Impacts of Combustion Modifications on Emissions</strong></td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Project will build on earlier efforts that assessed tradeoffs between the control of criteria pollutants (NOx, SOx, particulates), trace toxics (mercury, selenium, organics, and others) vs. CO2 and overall heat rate impacts. The project will document case study examples of member sites that encounter tradeoffs between emissions due to implementation of combustion modifications. Based on site-specific operational constraints, quantitative assessments will be made using available tools to support development of a methodology for identifying optimum boiler operational strategies.</td>
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<tr>
<td><strong>Evaluation of the Integration of Combustion Optimization Sensors with Optimization Technologies</strong></td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>One potential benefit of spatially resolved combustion sensors is the integration of their output into combustion controls systems in order to maintain optimized boiler operating conditions over time as well as changes in load. Based on case study examples from site-specific applications of combustion sensors, a review will be conducted of available boiler controls compared to benefits achieved. A primary objective of the evaluations is to identify the level of boiler controls required to fully respond and act upon information provided by combustion sensors.</td>
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<tr>
<td><strong>Emerging NOx Control Technologies Web Site</strong></td>
<td>12/31/12</td>
<td>Technical Resource</td>
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<tr>
<td>This project continues the Emerging Combustion NOx Control Technologies website, providing up-to-date findings, performance data, and performance impacts of all combustion-based NOx controls.</td>
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<tr>
<td><strong>Sensitivity of Air and Fuel Flow Balancing on Combustion Performance</strong></td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Builds on the information gathered in 2010 and 2011 through CFD studies and field tests of operating coal-fired power plants. The objectives are to determine the ability to improve coal flow balance and quantify the effect of improved flow balance on plant performance.</td>
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<tr>
<td><strong>Evaluation of Dynamic Coal Flow Control Methods</strong></td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>The EPRI Particulate Flow Loop (PFL) will be deployed to investigate devices to control coal flow distribution. Potential candidate systems include adjustable riffles, controllers, fixed-flow straighteners, and orifices. The effectiveness of each device will be assessed under a wide matrix of conditions that simulate actual plant environments.</td>
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</tbody>
</table>
Survey of Advanced Mill Optimization Technologies: The OEM and after-market industry offerings for advanced instrumentation and mill components will be summarized. The focus will be on online fineness and coal distribution, for both vertical spindle and ball/tube mills. The user base and experience, including performance improvements obtained, will be documented in a technical update.

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<tr>
<th>Product Title &amp; Description</th>
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<th>Product Type</th>
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<tbody>
<tr>
<td>Survey of Advanced Mill Optimization Technologies</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P71.003 Heat Rate and Cost Optimization (051807)

Key Research Question

Improving heat rate can reduce the cost of operation through fuel savings and increased availability. In addition, improving heat rate is by far the most cost-effective method and the only “ready now” method of reducing CO₂ levels.

Approach

This project group will develop and demonstrate a variety of deliverables and services that promote optimal heat rate and minimal cost of operations. Specific efforts will include heat rate program guidelines; economic evaluation of fuel quality impacts on heat rate; the effects of increased cycling and load-following operation; best practices for plant performance monitoring and improvement; and technology transfer vehicles such as conferences, workshops, and webcasts. In addition, participation will include membership in the Heat Rate Interest Group, where best practices, information, and prioritizing of available resources are shared. Finally, this project will house the Production Cost Optimization Interest Group, dedicated to seeking significant heat rate improvements for existing power generating facilities through cost-effective operational modifications, and significantly more improvements through more capital-intensive improvements.

Impact

- Reduce fuel costs
- Improve availability and emissions goals with existing hardware
- Realize future benefits, including reduced CO₂ emissions at costs far lower than those of post-combustion options

How to Apply Results

Participants can use project deliverables to assess and implement tools and technologies that improve plant performance and lower heat rate and CO₂ emissions. In addition, participants in full-scale demonstrations, which are available to all program members, can gain firsthand experience with issues and solutions. Participants can use deliverables to apply findings and best practices at their units, enabling savings in fuel costs, reduced CO₂ emissions, and increased productivity and availability.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Heat Rate Program Guidelines</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</tbody>
</table>

Heat Rate Program Guidelines: The project will continue the effort initiated in 2011 to provide an outline for a plant performance monitoring, testing, and improvement program through the incorporation of our routine performance guidelines and other industry standards, including the prior EPRI publications. Computer simulations incorporating boiler and turbine models will be conducted to determine the effect on heat rate of step changes in key operating parameters.
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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tr>
<td><strong>Methods to Mitigate the Effects of Increased Cycling and Load-Following Operation on Heat Rate:</strong> This project will build on the results of work completed in 2010 and 2011 to evaluate the methods used to mitigate the heat rate effects of increased load-following, using a series of field tests at sites where those methods have been employed.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Technical Conferences and Webcasts:</strong> These “members only” plant experiences meetings bring together member performance engineers in the industry to discuss their latest experiences in improving plant performance. The Cooling Tower seminar and conference brings together industry experts from utilities and vendors to discuss current issues and R&amp;D needs. In addition, quarterly technical web conferences will focus on key heat-rate-related topics as determined by funders.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Economic Evaluation of Fuel Quality Impacts on Heat Rate:</strong> Following up on the 2010 technical update, this project will further quantify fuel quality effects on operating plants via field testing at host sites.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Improved Fluid Flow Measurements:</strong> Best practices will be identified to improve and maintain accurate fluid flow measurements in power plant settings. Some methods used by calibration labs will be explored for application in field settings. This effort will address feedwater, condensate, circulating cooling water, and other fluid flow measurements.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Evaluation of the Application of Control System Advances to Improve Heat Rate:</strong> This project compares currently installed control systems to those available and identifies the advances required for a step-change improvement in plant heat rate. This is a joint effort with Program 68.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Cost-Benefit Evaluation of Steam Turbine Improvements:</strong> This project will evaluate the operating differences between full and partial arc admission, quantifying the expected changes in heat rate and reliability, and weigh those against any cost differences between the two admission schemes. It will also evaluate potential improvements to flow guides and LP turbine exhaust hood modifications. In addition, the project will quantify the expected gains in heat rate, estimate any reliability changes, and compare the gains to the costs for engineering, fabrication, and installation. These evaluations, one applicable to HP turbine and the other for LP turbines, will be conducted separately.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Rate of Coal Quality Degradation and its Effect on Plant Performance:</strong> The first year of this multiyear effort will search the open literature, poll members, and contact fuel suppliers to determine the effects on coal quality of variations in time, transportation mode, weather, and storage. The details of the degradation process will be analyzed. The rate of degradation is expected to depend upon fuel type, and this analysis will focus on U.S.-based coals in its first year. The project may be shared/coordinated with 71.002, depending on funding and prioritization.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Optimal Design of Steam Condensers:</strong> This study will evaluate recent advances in the state-of-the-art in condenser design, resulting in applications for both retrofits and new plant condensers.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Evaluation of the Effect of Unsteady or Changing Coal Flow Rates on Distribution and Transport Phenomena (e.g., For Load-Following Operation):</strong> This project will build on the results of the work completed in 2011 at the flow loop, through tests conducted at operating power stations experiencing increased load-following. The objectives are to determine whether the mass distribution changes and associated restraints and results (e.g., layout or pulsing flow) affect unit performance and reliability. The results of this project may feed into the other projects focused on determining the heat rate effects of increased load-following.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>
Supplemental Projects

Cyclone Boiler Performance Optimization (044771)

Background, Objectives, and New Learnings
Cyclone boilers represent a substantial fraction of the coal-fired boiler capacity in the United States and offer some of the lowest electricity generation costs. Production of cyclone boilers by the original equipment manufacturer ceased in the 1970s in response to the Clean Air Act and the difficulty of meeting NOx emission requirements under New Source Review standards in a cost-effective manner.

Due to shifting operating practices that have been adopted in response to recent environmental mandates, there is an ongoing need to address operational issues specific to cyclone boilers. The Cyclone Boiler Performance Optimization Group develops and demonstrates cost-effective solutions for improved operability and performance of cyclone boilers. Its research and development (R&D) fills a void in the marketplace, as no other organization currently focuses on the needs specific to cyclone boilers. Tasks that the group has adopted include establishing advanced diagnostic capabilities (for example, cyclone barrel fuel/air balance, individual cyclone barrel temperature measurement, real-time measurement of coal crusher size distribution, and unburned carbon in ash levels), which address increasingly more stringent NOx emission mandates, as well as the growing trend in spot market coal purchase.

Project Approach and Summary
The current project scope represents a continuation of work initiated in prior years, as well as new projects identified by project participants, with specific tasks including:

- Continued development of the Flame Doctor™ for application on cyclone boilers, with the goal of providing a tool for optimizing individual cyclone barrel operation.
- Assessment of real-time crushed coal size distribution, to enable an evaluation of factors contributing most to its variability and control.
- Real-time measurement of cyclone barrel temperature to provide unit operators with a diagnostic capability prior to encountering frozen slag taps.
- Application of tunable diode lasers to continuously monitor spatial concentration gradients of CO/O₂ to enable individual cyclone barrel tuning.
- Identification of maximum NOx reductions achievable with over fire air (OFA), in combination with validation of improved instrumentation capable of monitoring individual cyclone barrel operation.
- Projects in areas of interest identified as high priority by participating members.

Benefits
With collaborative research efforts focused on improving cyclone boiler operation and performance, value can be realized through improved boiler performance and operation, reduced operating costs, and a reduction in the unit forced outage rate.
Evaluation of Steam Side Conditions Leading to Waterwall Circumferential Cracking (070350)

Background, Objectives, and New Learnings

Circumferential cracking of the fireside surfaces of supercritical waterwalls remains a critical problem for many coal-fired boilers. To address this issue, a field study was conducted at Pennsylvania Power and Light’s (PPL) Brunner Island 3 (BI3), a 750-MW supercritical boiler prone to cracking problems, to assess operational considerations resulting in circumferential cracking. The test program was successful in: 1) Implementing a methodology to quantify thermal events (e.g., boiler tube temperature spikes) responsible for tube damage; 2) Quantifying the magnitude of these thermal events through an advanced thermal mapping system; and 3) Identifying a number of first-order operational correlations (e.g., wall blowing, load).

An interesting finding of the demonstration was that many of the thermal events could not be correlated with specific fireside operational parameters. An investigation of flow imbalances on the fluid side of the boiler tube is needed. Until these currently unexplained events are better understood, the identification and implementation of solutions to the cracking issue will be limited to fireside findings from the previous test program.

The purpose of the next phase of the project will be to continue to deploy the advanced thermal mapping instrumentation installed with additional, state-of-the-art fluidside instrumentation to potentially identify fluid imbalances and thermal impacts on circumferential cracking.

Project Approach and Summary

The primary objective of this project is to measure the fluid flow rate in selected waterwall tube circuits and then use this information, in combination with the existing diagnostic/troubleshooting instrumentation and analytical models, to assess the steam-side considerations of the BI3 waterwall cracking. This work will result in better understanding of steam-side impacts. A model subsequently will be used to evaluate the benefits of promising corrective actions. This effort will include a review of the costs and benefits of various combinations of corrective actions.

- The existing Rowan wall temperature mapping system will be used to assess tube temperatures.
- A state-of-the-art system to quantify fluid side flow and pressure measurements will be added to further study heat transfer variations in the supercritical transition range. A number of studies have reported a significant reduction in fluid heat transfer in this transition range.
- Tube-to-tube circuit flow instabilities will be assessed using currently installed instrumentation and the additional flow measurements.
- The resulting data will be reduced and analyzed to identify recommended operating parameters to minimize the quantity and severity of thermal events, the precursors to circumferential cracking.

Benefits

If left unresolved, tube cracking can lead to boiler tube failures, the number one cause of forced boiler outages. An improved understanding of the operating conditions that result in circumferential cracking allows this cause of tube failures to be addressed and mitigated.
Advanced Water-Conserving Cooling Technologies (067744)

Background, Objectives, and New Learnings

The electric power industry requires reliable access to large amounts of water, primarily for cooling. Growing demand for electric power, coupled with growing water demand in agricultural, municipal, residential, commercial, and industrial sectors, could strain water supplies in the future. Facing increasing pressures to improve water conservation and reduce water consumption at power generation stations, the electricity industry is investigating new and innovative technologies. These technologies may be plant and location specific.

This project will accelerate industry activities aimed at building confidence in advanced cooling technologies to reduce overall water use for power production by new and operating units. EPRI technical products and targeted demonstration projects will help minimize implementation and deployment risks while minimizing individual company expenditures.

Project Approach and Summary

This collaborative project, led by a team of EPRI and industry experts, proposes a range of projects to develop, test, and deploy efficient advanced cooling technologies. The projects will focus primarily on technology development and testing, but will also provide related information on economics, performance optimization, risk management, improved decision making, and public acceptance. This work will include a thorough investigation of geographic and power plant-specific considerations. Examples include the following:

**Power Plant Siting** – The availability of cooling water will play an increasing role in the siting of new thermal electric power plants. This project uses GIS-based watershed cycling models to develop and test a protocol to evaluate alternative sites, cooling systems, and cooling water sources.

**Meteorological Impacts on Air-Cooled Condensers (ACCs)** – Extreme circumstances such as strong, gusty winds can cause an ACC to trip and can affect unit operations. EPRI has pinpointed the cause of these wind effects. A simple ACC design change can be field tested to prove mitigation potential.

**Indirect Dry Cooling** – Indirect cooling systems, which use a dry cooling tower to cool the water circulating through the condenser, are most adaptable to nuclear units with secondary cooling loops. This project will evaluate performance and cost data from indirect cooling installations worldwide.

**Hybrid Tower Designs** – There is very little public information on the design, cost, and performance of hybrid cooling systems. This project investigates new hybrid designs that may offer better performance and/or lower costs and provides guidelines for the specification, design, construction, and operation of hybrid systems.

**Water Recovery Options** – At least two new systems that capture water from cooling tower plumes and stack gases will be tested to collect performance and cost data.

**Wet Surface Air Coolers** – EPRI has demonstrated a pilot wet-surface air cooler (WSAC) at more than 50 cycles of concentration with fresh water. This project will demonstrate the use of WSAC with degraded water sources such as municipal effluent.

**Advanced Bottoming Cycles** – These cycles offer potential cooling capability while also increasing station efficiency. EPRI and other entities have studied these cycles (ammonia and supercritical carbon dioxide) for more than two decades, but further demonstration is needed before members can adopt them for new facilities.

**Preserving Once-Through Cooling Options** – Permitting new, once-through cooling will require technical justification that ecological impacts are lower than those of cooling towers.
Benefits

Pressures to reduce overall water withdrawal and consumption are no longer limited to arid parts of the world such as the western United States. More-temperate climates are experiencing water constraints as a result of population growth, precipitation fluctuations, and changing demand patterns. These pressures and associated operating challenges are expected to grow significantly as utilities seek to permit and build new generation facilities to meet growing electricity demand.
Post-Combustion NOx Control - Program 73

Program Overview

Program Description
Selective catalytic reduction (SCR) technology has become the technology of choice for meeting stringent nitrogen oxides (NOx) emission limits for coal-fired electricity generating plants. More than 120 gigawatts (GW) of SCR capacity has been installed in the United States alone, and significantly more is planned for compliance with anticipated NOx mandates in the coming years, such as the EPA’s Clean Air Transport Rule (CATR). The Electric Power Research Institute’s (EPRI’s) Post-Combustion NOx Control program (Program 73) focuses on minimizing total costs and maximizing reliability and performance of SCR and other post-combustion NOx control systems.

Research Value
EPRI’s Environmental Controls programs develop technologies that minimize the impacts of environmental controls on power plant operations and performance. EPRI helps members evaluate and implement technology options to achieve their environmental performance goals at least cost. Post-Combustion NOx Control R&D provides:

- Development and implementation of best practices and operational improvements for SCR systems
- Lowered O&M expenditures, optimized operation, and reduced downtime for units equipped with SCRs
- Enhancements to existing SCR systems, which will allow members to profit from the NOx credit market

Approach
The program develops operating and maintenance (O&M) guidelines and documents best practices and procedures consistent with optimal SCR operation. Assessments, methodologies, and databases provide plant owners and operators with the tools to make informed choices, comply with regulatory mandates, and capitalize on NOx credit markets. Interest groups share best practices in SCR catalyst management and assess mitigation methods for large particle ash (LPA).

- R&D develops tools, guidelines, and best practices critical to optimum SCR operation, including catalyst management considerations, catalyst reconditioning options, SCR test protocols, and resolution of critical operability issues, including large particle ash (LPA), ammonia, and catalyst deactivation.
- Evaluations of advanced SCR and emerging post-combustion NOx control technologies allow members to significantly lower NOx emissions with existing SCR systems through improved ammonia/NOx mixing technologies and the latest advanced catalysts (offering higher efficiency and lower costs), and to find cost advantages for the most promising emerging NOx control technologies through compliance with near-term regulations and probable future regulations.

Accomplishments
For more than two decades, EPRI has led the power industry in developing, advancing, and demonstrating cost-effective NOx control technologies and best operating practices consistent with compliance achievement at minimal cost and maximum reliability. Accomplishments include:

- Performance assessments of SCR catalyst reconditioning
- Protocols for laboratory testing of SCR catalyst samples
- Annual SCR workshop and webcasts on key issues
- Assessments of improved performance achieved through enhanced ammonia/NOx mixing and advanced catalysts
- SCR O&M guidelines, updated annually
- Laboratory and field assessments of continuous ammonia monitors
• Catalyst management software and best practices for total minimization of total cost of operation
• Predictive tool for deposition of ammonium bisulfate (ABS) and subsequent fouling of air heater surfaces
• Case studies of impacts of fuel quality considerations (e.g., Powder River Basin and lignite) on catalyst performance and longevity
• Assessments of near-commercial NOx control technologies

**Current Year Activities**

The program R&D for 2012 will continue to focus on optimization of SCR performance and reliability, with the goal of minimization of NOx emissions at least cost. Specific efforts will include:

• Assessments of reconditioned catalysts (including activity, mercury oxidation, and SO2 oxidation)
• Low-load, load-following, and cycling operation
• Boiler/SCR optimization of NOx levels
• Catalyst management options for lowest overall cost of SCR operation
• Understanding and mitigation of large particle ash (LPA) impacts and ash deposition issues
• Development of technologies and practices with the goal of trouble-free year-round SCR operation
• Evaluation of advanced SCR technologies such as instrumentation for monitoring NH3, NOx, and SO3, new catalyst formulations, and assessments of other emerging post-combustion NOx control technologies.
• Catalyst disposal and recycling alternatives
• Prediction and resolution of air heater fouling, consequential to deposition of ammonium bisulfate
• Fuel, biomass co-firing, and operating effects on catalyst life
• SCR guideline updates
• Three webcasts that focus on key SCR O&M topics

**Estimated 2012 Program Funding**

$2.8M

**Program Manager**

Anthony Facchiano, 650-855-2494, afacchia@epri.com

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**Summary of Projects**

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P73.001</td>
<td>Post-Combustion NOx Controls</td>
<td>This project develops and demonstrates a variety of deliverables and services to promote identification of optimal post-combustion NOx levels, minimize operating costs, and document best practices for SCR performance monitoring and improvement. Emerging advanced SCR concepts are evaluated along with the effects of increased cycling and load-following operation. Conferences and workshops focused on key topics prioritized by participants are provided for technology transfer and staff development.</td>
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</table>
P73.001 Post-Combustion NOx Controls (070556)

Key Research Question
The industry needs reliable SCR O&M guidelines, documentation of best practices, and resolution of critical operability issues to minimize costs and maximize SCR system performance. In addition, in anticipation of more stringent NOx limits, methods of lowering SCR outlet NOx levels from both existing and new SCR systems — such as improved reagent/NOx mixing upstream of the catalyst, advanced instrumentation and control, or improved catalyst formulations — need to be developed and demonstrated. Finally, in anticipation of impending mercury and other hazardous air pollutants (HAPS) regulations such as the EPA Maximum Achievable Control Technology (MACT), SCR duties will be expanded to include co-benefits achieved from maximizing mercury oxidation while concurrently minimizing SO3 formation.

Approach
This project will produce guidelines, technical reports, software, webcasts, and conferences aimed at minimizing costs and maximizing performance of SCR and other post-combustion NOx control systems. Development and demonstration of advanced concepts geared towards minimizing NOx levels and maximizing mercury oxidation will be undertaken. Specific efforts will include:

- Assessments of reconditioned catalysts (including activity, mercury oxidation, and SO2 oxidation)
- Low-load, load-following, and cycling operation
- Boiler/SCR optimization of NOx levels
- Catalyst management options for lowest overall cost of SCR operation
- Understanding and mitigation of large particle ash (LPA) impacts and ash deposition issues
- Development of technologies and practices with the goal of trouble-free year-round SCR operation
- Evaluation of advanced SCR technologies such as instrumentation for monitoring NH3, NOx, and SO3; new catalyst formulations; and assessments of other emerging post-combustion NOx control technologies
- Catalyst disposal and recycling alternatives
- Prediction and resolution of air heater fouling, consequential to deposition of ammonium bisulfate
- Fuel, biomass co-firing, and operating effects on catalyst life
- SCR guideline updates
- Three webcasts will focus on key SCR O&M topics pertinent to improved SCR operation and performance, and “SCR 101” training webcasts will provide a refresher course on the fundamentals of SCR operation.

Impact
- Substantial reduction in the cost of SCR operation, achieved through best O&M practices and resolution of critical operability issues such as those associated with load-following or low-load SCR operation.
- Compliance with anticipated regulations, such as the EPA Clean Air Transport Rule (CATR) and Maximum Achievable Control Technology (MACT).
- Minimization of system costs through selection of the optimal SCR catalyst management strategies, including consideration of catalyst reconditioning options.
- Information about new advanced SCR concepts through independent evaluations on performance, costs, and operational issues.
- Member information exchange on best practices through program interest groups, SCR workshops, and webcasts.
- Minimization of SCR downtime.
How to Apply Results

Staff responsible for SCR operation and performance can use the tools, project reports, services, meetings, and webcasts developed through this project to optimize their SCR system O&M practices, auxiliary hardware choices, testing procedures and protocols, and catalyst management strategies.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>SCR Reconditioning Guidelines</strong>: Data on long-term performance of reconditioned catalyst is needed for informed purchasing decisions. This project will track the long-term performance of regenerated catalyst layers as a function of NOx activity, SO2 conversion, and mercury oxidation. Industry experience will be documented in comprehensive case studies and applied to a wide range of fuels, boiler types, and SCR operating conditions. Updated evaluations of new regeneration processes will be added.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<tr>
<td><strong>Load-Following and Low-Load Issues for SCR Operation</strong>: Economic conditions, the relative cost of gas vs. coal, and the proliferation of renewable dispatch have caused many SCR systems to operate in a load-following mode, or operate for extended time periods at low loads. This project will examine the issues associated with load-following and low load, including:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<td>- Options to alleviate temperature impacts at lower loads (e.g., economizer bypass or mods, feedwater temperature control)</td>
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<td>- Ash dropout issues at lower loads</td>
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<td>- Ammonium bisulfate and SO3 issues</td>
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<td>- Reagent controllability to minimize excessive slip levels while maintaining NOx levels</td>
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<tr>
<td>- Unit-specific case studies to assess real-world operational constraints and to evaluate options to cost-effectively alleviate constraints</td>
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<tr>
<td><strong>Boiler/SCR Optimization</strong>: Based on selected case studies and field tests conducted in support of the development of cost models, a methodology will be developed to enable SCR operators to better optimize SCR performance. Tools will be developed where needed to quantify potential cost tradeoffs between:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>- SCR inlet NOx level that results in the optimum combination of boiler- and SCR-related NOx control with respect to operating and maintenance expenses</td>
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<td>- Hg oxidation and NO reduction</td>
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<tr>
<td>- Changes in boiler SO3 emissions over the load range relative to SCR outlet emissions</td>
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<tr>
<td><strong>SCR Workshop and Proceedings</strong>: EPRI’s annual SCR workshop includes presentations on recent operating experiences by SCR operators, key issues such as SO3 mitigation, large particle ash (LPA) deposition and mitigation, catalyst management strategies, the latest developments by process suppliers and catalyst vendors, panel discussions, and a tour of an SCR-equipped coal-fired unit.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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<td>Product Title &amp; Description</td>
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<tr>
<td><strong>Catalyst Plugging:</strong> Catalyst plugging by LPA and fine fly ash is the major issue affecting catalyst performance. Undertakings to help mitigate this issue include:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<td>• Assessments of operating practices and impacts of flow properties of fly ash in SCR ductwork</td>
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<td>• Ash deposition mitigation techniques (e.g., duct mods and turning vanes), using modeling and field assessments</td>
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<td>• Demonstrations of newly-developed techniques for mitigating LPA and fly ash deposition</td>
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<tr>
<td>• Additional studies of LPA formation mechanisms (such as fuel properties, unit design and operation) and mitigation through combustion modifications</td>
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<tr>
<td>The Catalyst Plugging Interest Group (CPIG) will continue as a forum in which best practices can be shared and R&amp;D priorities identified.</td>
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<tr>
<td><strong>SCR O&amp;M Guideline Update:</strong> Key topics to be added in the SCR O&amp;M guidelines will include:</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<tr>
<td>• Methods for benchmarking unit-specific SCR performance with respect to the U.S. fleet of SCRs.</td>
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<tr>
<td>• State-of-the-art practices for mitigating ash deposition on catalyst modules, turning vanes, reactor inlet ducts, and NH3 injection nozzles.</td>
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<td>• Impacts on SCR performance of the transition from ozone season to annual operation.</td>
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<td>• Overview of best practices for low-load operation of SCR systems.</td>
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<td><strong>SCR O&amp;M Webcasts:</strong> Three 90-minute webcasts are held each year in April, June, and August, focused on timely SCR O&amp;M topics. Program funders are invited to recommend new topics. Examples of previously-covered topics include SCR impacts of switching to higher sulfur coals, biomass impacts on catalyst, and online monitoring of SCR systems.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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<tr>
<td><strong>Catalyst Management Issues and Interest Group:</strong> Documentation of first-order considerations and issues, which may include:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<td>• Case studies of catalyst management strategies that serve as models / lessons learned</td>
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<td>• Synthesis of other program elements pertaining to catalyst management, such as SCR co-benefits, boiler/SCR performance optimization, and catalyst deactivation, reconditioning, recycling, and disposal</td>
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<td>• Training session or webcast on the use of catalyst management techniques and tools.</td>
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<td>The Catalyst Management Interest Group (CMIG) will continue as a forum for sharing best practices and identifying R&amp;D priorities.</td>
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<td><strong>Recommendations for New SCR Systems:</strong> Lessons learned from the existing fleet of SCR systems will be documented, with the objective of defining features that should be incorporated in the design of future SCR systems. Topics may include:</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<td>• Design provisions for minimizing ash deposition</td>
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<td>• Methods for optimum ammonia and NOx mixing</td>
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<td>• LPA screen design and materials</td>
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<tr>
<td>• Design provisions and operating practices for low-load operation</td>
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<tr>
<td>• SCR co-benefits for Hg oxidation and SO3 mitigation.</td>
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<td>Product Title &amp; Description</td>
<td>Planned Completion Date</td>
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<tr>
<td><strong>Fuel Impacts on SCR Catalyst Deactivation Database</strong>: This project will study fuel and SCR operating impacts on SCR catalyst deactivation. The project will investigate technologies to prolong the life of catalyst activity. Research areas to include:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<td>- Implementation of continuous arsenic monitors</td>
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<td>- Phosphorous vaporization rates during high-staged combustion</td>
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<td>- Catalyst effects due to boiler startups/shutdowns and boiler washes</td>
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<tr>
<td>- Biomass co-firing impacts on SCR catalyst deactivation (co-funded with P84B)</td>
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<tr>
<td><strong>Effects of SCR Catalyst Formulations on Other Pollutants</strong>: Industry data has shown that, along with NOx reduction, SCR technology has the potential for oxidizing mercury, providing enhanced removal in downstream systems. This project will develop a model of mercury oxidation across SCR systems based upon EPRI and industry data. Newer catalyst formulations effects on other pollutants will be investigated (N₂O, NO₂, NH₃, SO₂, SO₃, and CO, co-funded with P75).</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<td><strong>Advanced SCR Concepts and Emerging Technologies</strong>: Advanced SCR concepts will include assessments of:</td>
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<td>Technical Update</td>
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<tr>
<td>- Revised control system approaches to reduce response time, lower maintenance costs, and incorporate the ability to achieve on-line SCR tuning capabilities</td>
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<td>- Advanced catalysts for ammonia destruction, mercury and CO oxidation, ultra-low SO₂ conversion, and poison resistance</td>
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<tr>
<td>- Emerging post-combustion NOx control technologies</td>
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<tr>
<td><strong>Disposal and Recycling of Spent SCR Catalysts</strong>: Continued exploration of catalyst disposal options will be conducted in light of regulatory changes. Previous studies have identified potential catalyst recycling options that warrant further investigation, including the utilization of spent catalyst in cement and concrete applications. This project will demonstrate potential cost-effective alternative to catalyst disposal.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<td><strong>SCR “101” webcast Training</strong>: Fundamentals of SCR — including basic chemistry, catalyst types, O&amp;M issues, and catalyst management — will be covered in two 90-minute webcasts.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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Supplemental Projects

Selective Non-Catalytic Reduction Performance Optimization (060642)

Background, Objectives, and New Learnings

Legislative mandates for additional NOx reductions have necessitated installation of post-combustion NOx control technologies on many coal-fired boilers. Current post-combustion NOx control technologies applied on coal-fired boilers have been limited either to selective non-catalytic reduction (SNCR) or selective catalytic reduction (SCR) systems. Although SCR provides higher levels of NOx reduction, capital and operating costs are very high. SNCR provides nominal NOx reduction levels of 20% – 30%, at relatively low capital costs, and with operational costs proportional to urea reagent consumption rates. As a result, SNCR systems have been broadly employed over the last decade on smaller-capacity boilers or older units with limited remaining life, where it is difficult to cost justify an SCR retrofit, yet incremental NOx reductions still are required.

Project Approach and Summary

Project meetings and webcasts discuss SNCR operational issues and research project results. Potential areas of focus of the SNCR Performance Optimization Group include exploration of operational and performance improvements through group-funded demonstration projects. Potential projects include:

- Improved NOx reduction with existing SNCR systems
- Implementation and testing of improved SNCR process control approaches
- Further testing of continuous spatially resolved ammonia slip monitors
- Testing of continuous furnace exit temperature monitors for optimization of reagent injection
- Characterization of new reagent injectors
- Reagent dilution approaches that minimize system impacts
- Additional projects will be conducted to address needs and issues as identified by group participants.

Benefits

By demonstrating the broader applicability of the SNCR technology with improved process control approaches, value can be realized through reduced operating costs and improved NOx reduction performance, as well as reduced balance-of-plant impacts due to lower ammonia slip levels. Information acquired by participating organizations also can pay off in reduced NOx compliance costs compared to commercially available alternatives.
Integrated Environmental Controls - Program 75

Program Overview

Program Description

Power generators need information on performance, applicability, and costs of controls for achieving the hazardous air pollutant (HAPS) emission limits in the U.S. Environmental Protection Agency's (EPA) March 16, 2011, proposed Maximum Achievable Control Technology (MACT) rule for Electric Generation Units (EGUs). Reasonable cost solutions remain a challenge in some cases, such as mercury capture in units that burn medium- or high-sulfur coal, as well as acid gases, selenium, and other condensables across a wider choice of fuels. This situation is especially true for power plants that cannot justify investment in selective catalytic reduction (SCR) for NOx and flue gas desulfurization (FGD) SO2 control, or, for those with wet FGDs, to avoid excessive costs and complexity in treating FGD waste water discharges.

In the face of continued pressure on electricity prices, power plants also need lower-cost and better-performing sorbents and technologies than those available today, especially for fuel/air pollution control configurations that otherwise would require the installation of multiple control devices. Other industry multipollutant control needs include systems to provide low- to medium-cost, moderate SO2 removals for older, smaller, “shoulder” units, with HAPS reductions as a co-benefit. Power plants with wet FGDs have additional needs: materials of construction that resist corrosion, updated guidance on selecting limestone reagents, and options for reducing water consumption. The drive for lower-cost air pollution control solutions through integrated environmental controls (IECs) leads to an industry need for independent, current information on costs and performance of any new IECs.

The Electric Power Research Institute’s (EPRI’s) Integrated Environmental Controls (IEC) program (Program 75) develops technologies and provides independent engineering evaluations and performance and cost assessments for systems that control HAPS, SO2, and other criteria pollutants, working in an integrated fashion with programs that address the impacts of these controls on particulate control, effluent discharge, compliance monitoring, and coal combustion product (such as fly ash and gypsum) use.

Research Value

The R&D focus in 2012 and beyond will develop and demonstrate cost-effective, robust controls for all power plant configurations/fuels that meet the final MACT limits for mercury (Hg), non-Hg trace metals, and acid gases. The specific activities will be dictated by the final rule, to be signed by November 16, 2011. Attention will be paid to minimizing the overall costs, including those for the controls; their impacts on criteria air pollutants, liquid discharges, and coal combustion products; and system reliability. Program members can benefit through:

- Data to support compliance decisions, especially whether to adopt the controls that formed the bases for EPA's proposed regulations; e.g., the ability of dry sorbent injection to reduce acid gas to the levels required by the final rule;
- Test data on the impact of startup/shutdown, cycling, and malfunctions on HAPs control effectiveness, as input into compliance strategy analyses;
- Solutions for pollutants for which controls have not yet been developed, such as selenium and mercury at plants burning medium- or high-sulfur coals;
- Strategies to reduce SO3 and, potentially, other condensables (e.g., ammonia, selenium) in the event condensable particulate matter limits, as proposed, remain in the final rule (in conjunction with EPRI Programs 71, 73, and 76);
- Lower-cost technology options (e.g., on-site activated carbon production; fixed structure adsorbents to avoid sorbents with their consequent impact on fly ash collection and usability, as well as FGD water discharge and gypsum usability);
Flue gas desulfurization (FGD) operational practices, additives, or limestone properties that enhance capture of soluble HAPS; and
Information about emerging IECs, which can save $10,000 to $20,000 compared to the cost to acquire the data in-house.

Approach
The program helps power companies minimize the costs of complying with the promulgated MACT standards through the development and testing of controls for the regulated HAPS that are more cost-effective, have lower operations and maintenance (O&M) costs, and have fewer balance-of-plant impacts than today’s offerings. It also helps plant operators optimize operating practices for maximum FGD reliability and multipollutant capture, along with reduced water use, all without undue impact on FGD discharge water treatment.

- Multipollutant (aka IEC) Technology Evaluations and Databases conducts technical analyses of emerging IEC processes; updates IECCOST software, which allows users to analyze IEC options for their specific sites; and develops projects to obtain independent test data on large pilot or early commercial installations.
- HAPS technology development research completes the ~20-year cycle of developing mercury controls by addressing the remaining gaps; identifies or conceives, develops, and demonstrates least-cost controls for the other HAPS that will be limited by EPA, with special focus on achieving anticipated EPA regulatory levels through co-benefits from mercury and SO2 controls; continues to conceptualize, develop, and demonstrate novel concepts for lower-cost HAPS (especially mercury) reduction; and demonstrates techniques to avoid re-emissions in SO2 scrubbers and drive captured mercury to desired discharge streams.
- Research on FGD operation for optimized multipollutant control, improved reliability, and minimized water use/discharges develops “lessons-learned” guidelines for continuous, ultra-low SO2 emissions; updates EPRI’s Materials Selection Guidelines, including countermeasures for corrosion issues being experienced by many power companies (e.g., the 2205 alloy issue); determines the role of limestone impurities in mercury and selenium capture, absorber corrosion, and gypsum quality; and evaluates the cost and performance of potential water-saving concepts.

Accomplishments
EPRI’s annual reports on HAPS controls (recently expanded from a sole focus on mercury to other HAPS) are recognized in the electricity industry as an authoritative source for independent, up-to-date information. In addition to being considered a valuable technical resource by power company staff, they have been used by members to educate regulators about control technology capabilities and status. The reports detail:

- Real-world data on mercury control by sorbent injection and chemical addition for many fuels and pollution controls, including impacts on ash, scrubber performance and corrosion, water discharge, and ash or gypsum use in industry.
- Progress in understanding how to manipulate FGD chemistry to manage captured mercury and selenium — avoid re-emissions and drive the captured species to the species and discharge with least downstream impact.
- Control approaches and countermeasures to minimize the impact of mercury controls on ash and gypsum usability, or on the difficulty of landfilling it.
- Progress in developing and demonstrating novel mercury controls that offer the potential for lower-cost or fewer plant impacts (e.g., on-site production of activated carbon using coal being burned by the plant).

Participants also receive value from technologies developed by EPRI aimed at improving the performance or lowering the cost of HAPS control. In recent years power companies installed more than 8,000 megawatts (MW) of TOXECON®, an EPRI-patented process for capturing air pollutants, demonstrating an option for high-mercury and particulate (hence non-mercury trace metal HAPS) removals with no impact on ash usability. Value received from other past accomplishments include:
• EPRI’s database on emerging IECs and its economic comparisons of IECs with conventional controls have helped power companies assess these options with minimal in-house effort and respond quickly to queries about their applicability.

• EPRI’s tests of the ECO®, ReACT®, and NeuStream-S™ processes have provided potential users with independent performance data, facilitating their assessment of these technologies.

Current Year Activities

The program R&D for 2012 will be driven by the final MACT rule. Currently (mid-2011), EPRI expects this program to focus on reducing the few remaining uncertainties in mercury emissions control while increasing emphasis on controls for the other volatile metal HAPS (primarily selenium) and for acid gases in unscrubbed units, dealing with early mercury control implementation issues, providing guidance on new materials of construction for FGD absorber vessels, and lowering scrubber water use. Specific efforts will include:

• Development and demonstration of controls for selenium, acid gases for non-scrubbed units, and other condensables (in case the final rule retains the condensables limit in the proposed rule), with a focus on seeking least-cost approaches through co-benefits of mercury-specific or dry alkali

• Assessment of HAPS emissions during startup, shutdown, load ramping, and malfunction, along with development of strategies to minimize those emissions during those periods

• Resolution of remaining mercury control issues, especially re-emissions from SO₂ scrubbers, sorbents for medium-high SO₂ flue gas or use at plants with hot-side ESPs, and impacts on ash or gypsum use

• Demonstration of novel, much-lower-cost controls for mercury and other HAPs, such as fixed structures or on-site generation of activated carbon and lime/lime hydrate

• Updated guidelines for selecting materials of construction for FGDs, including countermeasures for accelerated corrosion of alloys such as 2205

• Pilot tests of enabling technologies for water minimization in wet SO₂ controls

• Possible field tests of promising new IECs, with an expanded scope to include HAPS as well as criteria air pollutants

Estimated 2012 Program Funding

$5.0M

Program Manager

Anthony Facchiano, 650-855-2494, afacchia@epri.com

Summary of Projects

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<tr>
<th>Project Number</th>
<th>Project Title</th>
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<tr>
<td>P75.001</td>
<td>Multipollutant Technology Evaluations</td>
<td>This project seeks or develops and evaluates new IECs as they become known, or as significant improvements are announced or communicated to EPRI. The project develops cost models, which are added to IECCOST. It also supports the testing of promising IECs.</td>
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<tr>
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<td>and Databases</td>
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<tr>
<td>P75.002</td>
<td>Hazardous Air Pollutant Control</td>
<td>This project finds or develops and demonstrates least-cost, lowest-impact, robust emission controls for HAPS (including mercury) for all fuels and criteria air pollution control systems.</td>
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<td></td>
<td>Technology Development</td>
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<tr>
<td>P75.003</td>
<td>FGD Operation for Optimized Reliability,</td>
<td>This project demonstrates performance of optimized scrubber systems for very low emissions of SO₂ and other acid gases with high availability and limited corrosion. For “shoulder” units, it demonstrates cost-effective moderate SO₂ removal processes. For water-constrained plants, it provides methods to reduce the FGD-related water consumption as part of a plantwide reduction plan.</td>
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<td>Emissions and Water Usage</td>
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P75.001 Multipollutant Technology Evaluations and Databases (052528)

**Key Research Question**
Developers continue to offer new integrated environmental controls (IEC) with the promise of lower costs than serial application of single-pollutant controls. Often the target market is smaller, older “shoulder” units that cannot afford large capital cost retrofits, but still will need significant pollutant reductions under the recently proposed EGU MACT to continue operating. To ensure they have a least-cost multipollutant compliance strategy based on the best possible information, power companies need up-to-date information on available technologies, both newly emerging and previously evaluated (many of the latter have changed or are no longer being pursued).

**Approach**
EPRI continues to gather intelligence from its members and other sources on new IEC processes. As it finds them, EPRI collects information from the developers and users, summarizes the information, and shares it with its members via web postings. Promising processes may be assessed further for technical feasibility and economic benefits. Some of these new processes may be EPRI-developed or private sector-developed and EPRI-enhanced. Periodically, EPRI updates its IECCOST software worksheet for use by power companies to develop site-specific cost comparisons of multipollutant control options. When IEC processes are being demonstrated, EPRI seeks to serve as an independent performance test manager.

**Impact**
- Save up to $20K in avoided costs per process, using EPRI evaluations in lieu of in-house studies. Also receive quick responses to questions raised by management or the public about new processes.
- Potentially save 10%–25% in levelized cost by using IECs instead of single-pollutant controls; possibly save more with very simple EPRI processes in which moderate reductions are acceptable and large investments cannot be justified.
- Enable in-house staff to quickly estimate the costs of various multipollutant control options for compliance strategy analyses.

**How to Apply Results**
Plant or corporate engineers can use the EPRI reports — including engineering and economic analyses and field test reports — to understand a new process when reporting to management, working with a developer, or conducting a technology search for cost-effective multipollutant controls. Engineers can keep abreast of ongoing developments through the quarterly advisor updates and can conduct their own site-specific cost estimates of different control options using IECCOST, either directly or via a contractor.

**2012 Products**

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<th>Product Title &amp; Description</th>
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<th>Product Type</th>
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<td><strong>2012 Status of Multipollutant Process Developments</strong>: Updated evaluations of new or improved processes. Accompanying update of IECCOST, if promising new technologies are found and sufficiently developed or cost components change significantly.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>
P75.002 Hazardous Air Pollutant Control Technology Development (065775)

Key Research Question

The U.S. Environmental Protection Agency (EPA) proposed Maximum Achievable Control Technology (MACT) standards for Electric Generating Units (EGUs) on March 16, 2011, and is under a court mandate to promulgate final regulations by November 16, 2011. The proposed regulations stipulate emission limits for all listed hazardous air pollutants (HAPS) emitted by EGUs — mercury, other trace metals (including selenium), acid gases, and organics (via work practices). While controls for mercury generally are well understood, challenges remain for ensuring the low proposed emission limits can be met continuously, and that solutions exist for power plants with SO₃ in the flue gas. Most non-mercury trace metal HAPS are contained in the fly ash, so their emissions can be reduced to low levels by highly efficient particulate controls — baghouses, and perhaps electrostatic precipitators — but control strategies for selenium (which exists as both a vapor and adsorbed onto fly ash) are not well understood. Acid gases can be controlled effectively by wet or dry flue gas desulfurization (FGD), but it is not known if lower-cost approaches, such as injection of an alkali into the flue gas duct upstream of a particulate control, are adequate as postulated by EPA in the proposed rule. The industry also needs guidance on how to implement work practices for organics as well as ways to deal with the CO-NOₓ trade-off if EPA replaces work practices with an emission limit, such as for CO. Overall, the industry needs independent assessments of the performance of current HAPS control options. More importantly, it needs development and demonstration of controls on fuel and air pollution control configurations for which current system performance is not widely proven, adequate to meet the proposed limits, or too costly. Further, these controls also must have limited or manageable balance-of-plant impacts and not increase other pollutants, invoking New Source Review (NSR).

Approach

In 2012, this project will focus on solutions to the pollutants newly proposed for regulation under the EGU MACT, while addressing the remaining challenges for mercury. Specifically, the project will:

- Determine the effectiveness of dry sorbent injection technologies, working together with high-efficiency particulate controls, in capturing SO₃, selenium, acid gases (primarily HCl and HF), and other condensables. These efforts are aimed at finding and evaluating or developing and demonstrating methods to avoid the negative effects of SO₃ on mercury capture by sorbents, controlling the other vapor-phase HAPS proposed for regulation, and mitigating the compliance (monitoring) difficulties associated with a condensables particulate matter limit as a surrogate for selenium.
- Demonstrate high-performance, cost-effective mercury emission controls for challenging fuel/air pollution control combinations, with emphasis on (a) sorbent injection in SO₃-containing flue gas and (b) co-benefits of selective catalytic reduction (SCR) for NOₓ control and FGD for SO₂ control (managing the FGD chemistry to minimize mercury re-emissions)
- Address issues encountered during operation of mercury controls by state-regulation-driven early adopters
- Promote capture of vapor-phase selenium by wet FGDs while keeping the captured selenium in an oxidation state that does not create a water discharge issue.

Efforts will be coordinated with Program 76 (Particulate & Opacity Control) to determine the least-cost solutions that existing ESPs would need (upgrades or baghouse replacement/addition) to a) meet the stringent MACT particulate emission limits proposed as a surrogate for the solid-phase trace metals, or b) avoid particulate emission increases due to sorbent injection. Research to reduce SO₃ emissions will be coordinated by this project but conducted largely by Program 71 (Combustion Performance and NOx Control) for combustion modifications that can reduce SO₃ formation; Program 73 (Postcombustion NOx Control) for lower SO₂ oxidation catalysts; and Program 76 for advanced power supplies that can replace SO₃ flue gas conditioning for capture of high-resistivity particulate. If EPA reverses its proposal and sets emission limits on organic emissions (probably via a surrogate such as CO), EPRI will determine if new technologies are needed to achieve these levels and what research might be needed to develop or demonstrate them. A research plan will be developed and proposed to the funders at that time; this plan will be conducted jointly with Program 71.

The mercury control technology development and demonstration effort will retain its recent focus on continuous achievement of high capture levels on all units and fuels while reducing costs and also co-capturing other HAPS (especially selenium).

For scrubbed units, the goal is to control mercury via co-benefits, EPRI expects to bring to closure in the 2012-13 time frame the R&D needed to demonstrate consistent compliance with the low mercury emission limits in the proposed MACT rule. The primary approach is reliable, high-capture rates of oxidized mercury, largely by minimizing re-emissions. This work will address all sources of oxidized mercury — inherent or induced via catalysts or chemicals (e.g., halogens) added to the flue gas. Related objectives are to prevent mercury adsorption by gypsum intended for re-use, and avoid levels of regulated species (e.g., selenium) in the water discharge that exceed permit levels or are difficult to treat. In parallel, EPRI will continue to investigate alternate methods to capture mercury that do not depend entirely on scrubber chemistry, such as fixed structures placed in the flue gas duct just downstream of the mist eliminator that adsorb and bind the captured mercury (i.e., polishing devices).

The specific R&D approaches that will be followed in 2012 and beyond depend on both the final MACT rule and the results of the 2011 activities, which include long-term simultaneous measurements of both emissions and scrubber chemistry; continuing attempts to mechanically separate high- and low-mercury-content gypsum; and the use of additives that bind the captured soluble species (especially mercury and selenium) in readily separable solids. Based on findings in late 2010/early 2011, the research is expected to focus on the effects of limestone impurities, oxidation/reduction potential (ORP), and pH on the behavior of mercury and selenium (also on scaling) in a scrubber. It also may include sorbent or chemical addition technology for units relying on co-benefits, but achieving only 75-85% mercury capture when 90+% is required. EPRI may continue work from 2009-11 to understand and, as needed, mitigate potential impacts of adding halogens for mercury capture on FGD water discharge treatment systems, bioreactors that may be used for other HAPS, and other uses of the discharged cleansed waters.

For unscrubbed units, R&D will address:
- Measures to achieve MACT mercury emission limits at plants with > 2-5 ppm SO₃ in the flue gas post-air preheater or equipped with a hot-side ESP;
- Procedures, technologies, and instruments and controls (I&C) to enable continuous compliance with the proposed mercury emission limits for existing units, including operations during startup/shutdown/malfunction/load ramping;
- Lessons learned by early adopters of mercury controls through site surveys;
- Identifying and mitigating balance-of-plant issues (e.g., air preheater cold end corrosion, halogen buildup in scrubbers, loss of ash sales); and
- Testing of new approaches to reduce costs, sorbent consumption, and/or impacts on fly ash capture or use (e.g., on-site carbon production; novel sorbents; fixed structures such as honeycombs, plates).

By 2012, EPRI expects that some of the novel concepts currently being investigated under its Technology Innovation program will reach a maturity level that justifies transferring the further development to Program 75. These concepts include methods to de-agglomerate sorbents for injection of ultra-fine materials; addition of nano-sized iron particles; altering the carbon surface/chemistry to increase sorption capacity and affinity for other vapor HAPS; and using iodine or chlorine in lieu of bromine when making halogen-impregnated activated carbons for use with Powder River Basin (PRB) and lignite coals.

Impact

This project provides information that industry can use in informing policymakers and regulators on emission limits, and HAPS emission control technologies that are lower-cost, more widely applicable, and have less impact on plant operations than current technologies. With a greatly reduced federal government role in this area, EPRI now provides the main venue for developing, validating, and improving emission controls for mercury and other HAPS. Specific benefits from this project include:

- Availability of mercury controls for fuel/air pollution configurations not currently well-served;
- More and lower-cost mercury control options for all units;
- Third-party data on most promising, realistic HAPS control options for compliance planning and permit applications;
- Avoided capital and O&M costs for separate HAPS controls at plants already equipped with criteria pollutant and mercury controls;
- Reduced balance-of-plant impacts due to HAPS controls, such as increased particulate emissions, reduced bag life or increased pressure drop across baghouses, corrosion (especially due to bromide addition or activated carbon-catalyzed SO2 oxidation), loss of ash sales, and discharge to the FGD water treatment system of difficult-to-remove species;
- Reduced risk that FGD gypsum no longer is usable for wallboard manufacture and agriculture due to HAPS contaminants, with average savings of $10 to $20/ton gypsum from avoided landfill costs and gypsum sales;
- Independent performance data to guide procurement of least-cost, least-impact mercury controls in unscrubbed units — sorbent injection or otherwise; and
- Reduced risk of unknown issues in commercial applications.

How to Apply Results

Members can use project reports, technical updates at advisor meetings and webcasts, and communications with EPRI staff to learn about the capabilities and limitations of mercury and other HAPS controls available or being developed for their specific fuels and air pollution controls. This knowledge is useful externally and internally to inform policymakers, regulators, and management about the actual state of the technology in mercury/HAPS controls. For compliance planning, members can use the project results to create a plan with a greater degree of confidence; develop procurement packages for mercury/HAPS capture; evaluate new processes being introduced by developers; and select technologies and suppliers with reasonable risk.

2012 Products

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<tr>
<td><strong>State-of-Technology for Non-Mercury HAPS Control</strong>: Update of 2011 assessment and R&amp;D developments for those HAPS being regulated by EPA under its promulgated (by 2012) MACT rule.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>
**Mercury Control Selection Guideline:** Synthesis of available mercury controls with applicability, performance, user experience, and costs to enable power plant owners to select the optimum option for each of their units, given the existing/planned criteria air pollution controls and fuel procurement strategies. The guideline will address both scrubbed and unscrubbed units, and it will combine lessons learned from 2010-2012 site surveys with technical assessments of new technologies nearing the end of the development pipeline. It also will include O&M guidelines.

12/31/12 Technical Report

**HAPS Capture by FGD: Chemistry Management for Effective Vapor Phase HAPS Reduction, Gypsum Quality, and Waste Water Treatment:** Laboratory, slipstream pilot, and full-scale results of tests to demonstrate high mercury capture rates (largely by minimizing re-emissions), prevention of mercury adsorption by gypsum intended for re-use, and avoidance of regulated species (e.g., selenium) in the water discharge that are difficult to treat.

12/31/12 Technical Update

**Future Year Products**

**State-of-Technology for HAPS Control:** Summary of research results in 2012-13 on HAPS controls and supporting science. Focus is on the science and detailed learnings for the benefit of power company researchers and their contractors.

12/31/13 Technical Update

**HAPS Control Advances: Summary of Research Results:** Status of control technology developments and early application experience for those HAPS being regulated by EPA under its MACT rule, as of 3Q 2013. Includes mercury and nonmercury HAPS. The practical applications focus helps support decisions (R&D results in companion product).

12/31/13 Technical Update

**State-of-Technology for HAPS Control:** Status of control technology developments and early application experience for those HAPS being regulated by EPA under its MACT rule, as of 3Q 2014. Includes mercury and nonmercury HAPS. The practical applications focus helps support decisions (R&D results in companion product).

12/31/14 Technical Report

**P75.003 FGD Operation for Optimized Reliability, Emissions and Water Usage (052532)**

**Key Research Question**

Coal-fired power plants face wider application of SO₂ controls to comply with the proposed Clean Air Transport Rule (CATR) and the current Clean Air Visibility Rule/Regional Haze Rule. SO₂ controls also are one choice for meeting the acid gas (hydrogen chloride and hydrogen fluoride [HCl and HF]) limits in the proposed MACT rule. While required to operate at consistently high SO₂ removal rates, including during startup/shutdown/malfunction periods, these systems also are expected to capture any gas-phase HAPS that reach them. At the same time, new materials of construction have become available since the last wave of installations in the 1990s, and recent experience has not been positive with some of these alloys. Solutions are needed for the existing corrosion problems and to guide materials selection in future procurements. Further, the growing concern over water shortages is putting pressure on power plant operators to reduce consumption wherever they can, including in their wet FGDs. Longer-term, the industry should prepare itself to provide ultra-low SO₂ concentrations in the flue gas sent to a post-combustion CO₂ capture system.
As SO₂/acid gas controls are pushed to their performance limits, they require greater attention and expertise to select and operate. Power companies, especially those new to FGDs, can benefit from assistance in procuring new controls, specifying removal efficiencies and outlet emissions, and operating their new units most cost-effectively. On the expectation that the final CATR rules for SO₂ will allow some trading or intermediate-level reductions on smaller emitters, power companies also need very low- to moderate-cost, moderate-removal SO₂ controls for plants that cannot justify a high-capital-expense retrofit.

**Approach**

This project will update EPRI's materials selection guidelines for FGD absorber vessels, including additional sections that discuss best operational practices for minimizing corrosion while maximizing multipollutant capture, minimizing water consumption, and maintaining gypsum quality for use or easy disposal. It also will investigate opportunities to reduce power plant water consumption, either by alternative means of cooling the incoming flue gas or by using the FGD to evaporate waste waters. Determining the ability of wet FGDs to capture particulate, and to understand the factors that define that performance, is another project research thrust. The project also will serve as a central repository for lessons learned by the first wave of new FGD technology installations, including EPRI's understanding of the issues being experienced and approaches used to manage them. Program funders can participate in the SOx Control Interest Group (SOXIG), in which best practices and lessons learned on FGD operational issues are shared in an informal setting through an annual meeting and teleconference.

For “shoulder” units, the project will identify and demonstrate very-low-capital-cost, moderate SO₂ removal systems, including integration with particulate control, to the extent that new, promising technologies are found and can be matched with interested hosts.

Specific R&D topics may include:

- Surveys and engineering evaluations of operating experiences with current generation materials of construction for FGD absorber vessels, including measures to mitigate or counter corrosion. Supporting tests as necessary (conducted in collaboration with P87 Fossil Materials and Repair);
- Laboratory, slipstream pilot, or full-scale tests of limestone properties and FGD operating parameters (e.g., pH, ORP) that affect corrosion, gypsum quality, and the fate of the mercury and selenium captured by the FGD;
- Assessment of scrubber and spray dryer abilities to capture fine filterable particulate matter;
- Determination of the ability of advanced sensors/instrumentation to enable continuous operation at peak performance and avoid trips or the need for derates (e.g., use of the EPRI-developed On-Line Chemistry Monitor in an expert system such as FGDesert);
- Benefits of performance-boosting additives (whether applied continuously or episodically to overcome temporary emission excursions), while ensuring they do not adversely affect the capture of HAPS or water discharges;
- Methods to decrease FGD water consumption, such as gas-gas heat exchangers that reduce flue gas temperature ahead of the particulate control and FGD (which also could enable recovery of flue gas moisture post-FGD); alternatives to brine concentrators; or approaches to reducing brine concentrator energy consumption through integration into the plant's thermal cycle; and
- Approach to near-zero emission (NZE) levels achieved in practice by the combination of a wet FGD followed by a wet ESP or a simple/compact/dry polishing system.

**Impact**

- Avoid power replacement costs due to scrubber trips or destructive corrosion
- Minimize personnel and material costs of replacing scrubber materials
- Meet the proposed MACT particulate emission limits with minimal additional capital equipment
- Extend the commercial viability of smaller, older plants with very low-cost, moderate-removal SO₂ controls
- Minimize load reductions due to water scarcity (as part of an overall plant water savings response)
- Understand the ability of current/emerging generation SO₂ controls to satisfy the flue gas cleanliness requirements of amine-based and other CO₂ controls
How to Apply Results

Results can be used to ensure that procurement specifications for new SO₂ controls include all necessary parameters and advantageous performance levels, including reductions in other acid gases. Operators of existing units can use FGDExpert and EPRI staff expertise to implement procedures that maximize system performance for very high availability. Planners/engineers can use the reports to determine the feasibility of implementing a very low-cost SO₂ control and to develop the specifications to include in a request for proposal/request for quotation (RFP/RFQ).

2012 Products

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<tr>
<td>Options for Saving Water in Power Plants Equipped with an FGD: This project will provide concepts, designs, operation experience, and quantified benefits of methods to use the FGD to save water, including gas-gas heat exchangers (cyclic reheat), make-up spray into the mist eliminator, water recapture post-FGD, and trade-offs with increased cycles of concentration.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Performance of FGD Systems Optimized for HAPS Control and Durability: Annual update on lessons learned and emission results at plants with very low SO₂ emissions, effective multipollutant capture (vapor phase and fine particulate), and manageable corrosion. Will include research at all scales to support robust, high-performance FGD operation, experience and benefits of using advanced sensors, and performance of any next-generation designs for which commercial operational data are available.</td>
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Future Year Products

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<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td>Strategies to Reduce Water Consumption by SO₂ Controls: Final report on field experience with water minimization strategies, including impact on SO₂ capture, FGD O&amp;M (e.g., scaling and corrosion), gypsum quality or pond behavior, and actual water reduction achieved. Quantification of benefits and costs, where possible.</td>
<td>12/31/14</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Performance of FGD Systems Optimized for HAPS Control and Durability: Synthesis of a multiyear program, studying operating experience and emission performance at plants with very low SO₂ emissions, effective multipollutant capture (vapor phase and fine particulate), and manageable corrosion. Will include research at all scales to support robust, high-performance FGD operation, experience and benefits of using advanced sensors, and performance of any next-generation designs for which commercial operational data are available.</td>
<td>12/31/14</td>
<td>Technical Report</td>
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Supplemental Projects

Advanced FGD Process Control for Mercury and Selenium Removal (072048)

Background, Objectives, and New Learnings
Many existing and all planned coal-fired power plants use flue gas desulfurization (FGD) units to control sulfur dioxide (SO₂) emissions. Capture of volatile metals, such as mercury (Hg), selenium (Se), and potentially arsenic (As), also takes place in wet FGD systems. Efforts to understand the parameters that control Hg and Se emissions has been a high-priority research and development area. Understanding what influences their removal is important, but it also is important to understand the ultimate fate of these species in waste product and liquid streams. As many new FGDs are installed in response to several regulatory initiatives — the proposed Clean Air Transport Rule (CATR); the proposed Maximum Achievable Control Technology (MACT) rule for Hg, Se, and other hazardous air pollutants; and the Clean Air Visibility Rule (CAVR) — the need grows to understand these behaviors so they can be managed properly.

Vapor-phase selenium not adsorbed onto fly ash and captured by the particulate control device (electrostatic precipitator [ESP] or baghouse) may be captured in the wet FGD, although the reported capture efficiency has varied widely. The Hg and Se captured in the FGD eventually are discharged in the FGD solids /or water blowdown. Available data suggest that the fraction of selenium in the wastewater may vary widely from site to site, and more importantly the specific species of Se will determine the treatment required to meet stricter liquid discharge limits. Recent advances in understanding of Se speciation and Hg partitioning in the FGD liquor are providing direction for the development of control strategies that will maximize capture of vapor Se by the FGD and present it to the blowdown as the easy-to-treat selenite species. Because Se exhibits complex interactions with mercury, which could affect the design of mercury control strategies, management of the two in the FGD is linked and needs to be understood.

This project will demonstrate at full scale the control strategies being developed under current EPRI and DOE studies. It will establish new learning by demonstrating an integrated approach to managing wet FGD process chemistry to minimize Hg in the product gypsum (feedstock for wallboard and other uses) and simultaneously promote the formation of the more easily treated selenite compound in the FGD blowdown. The public will benefit through lower mercury emissions, greater use of the gypsum product, and lower Se discharges into water bodies.

Project Approach and Summary
This project will develop and implement an advanced FGD process control to optimize selenium speciation, mercury capture, and mercury partitioning to a manageable solids fraction that can be separated from the commercially useful gypsum product. The process control strategy will include added capability to maintain key process variables in a range that optimizes process chemistry to control the fate of selenium and mercury collected in the FGD system, while not affecting the FGD’s primary function — capture of SO₂. The project will evaluate the long-term operability of the control system changes to ensure that the objectives can be maintained over the expected range of operating conditions.

Benefits
This project will demonstrate at full scale the application of findings from several ongoing EPRI projects that are developing an understanding of mercury and selenium chemistry in FGD systems:
- Controlling selenium speciation in the FGD process will allow more efficient and cost-effective removal by the wastewater treatment system.
- A more integrated approach to toxic removal and treatment can be provided by optimizing the FGD process to maximize mercury capture by the FGD, through preventing re-emissions, and to enhance the salability of the product gypsum by partitioning the mercury into an enriched solids stream that can be separated from the commercially useful gypsum.
Power Plant Wastewater Treatment and Management (071888)

Background, Objectives, and New Learnings

The electric power industry is facing many new federal and state regulations and community pressures that will affect how power plants use and discharge water. These pressures are already impacting the availability and operation of existing plants and permitting of new generating units. Over the next decade, as new control technologies and new fuels (such as biofuels) are deployed to satisfy more-stringent air pollution limits, releases to wastewater and solid waste streams may contain new or greater amounts of contaminants. These changes will require the use of new or enhanced water management and treatment approaches.

Meeting these challenges requires a comprehensive approach to managing power plant water, including initial withdrawal, characterization of wastewaters, treatment options to meet reuse water quality requirements or discharge limits, and ultimate fate in the environment. A key component of this research project is to ensure the availability of a range of control technology options for managing and treating various high- and low-volume discharge streams.

Project Approach and Summary

The project proposes initiation of key research activities focused on wastewater treatment technology development for fossil power plants. Based on industry feedback, the following technology development areas are particularly critical:

- Evaluation of treatment technologies focused on removing mercury and selenium (as well as other pollutants) from FGD and other wastewaters.
- Evaluation of treatment and management approaches for low-volume (non-ash, non-FGD) wastewaters, including recycling and reuse.
- Evaluation of thermal zero-liquid-discharge (ZLD) approaches to evaporating and reusing wastewaters. This research will include the management of solid residues (full ZLD) and brine concentrate (partial ZLD), as well as materials of construction to avoid corrosion.

The specific 2011 work scope will be finalized by the project funders based upon available funding. This research will be coordinated with separate wastewater treatment projects addressing hybrid biofilm reactor and iron coprecipitation for FGD water treatment, hybrid zero-valent iron for removing toxic metals from industrial wastewater, and full-scale vertical flow wetland performance monitoring.

Additional R&D is needed to evaluate novel and promising approaches for water treatment. A literature and vendor survey will be conducted to identify additional promising technologies for review and prioritization by EPRI and the project funders. Promising technologies include:

- Nanotechnology for selenium and mercury treatment,
- Novel activated carbon approaches,
- Novel iron-based reagents,
- Microfiltration targeting submicron mercury particles, and
- Ettringite coprecipitation for boron and selenium.

A secondary function of this project will be to create an interest group forum for participating companies to share information on wastewater discharges and treatment/management approaches. EPRI will organize several meetings or teleconferences during 2011 to provide a forum for these discussions; present the latest data, issues, and findings; and discuss new initiatives.
**Benefits**

This research project will accelerate characterization of power plant liquid discharges and the ability to reduce pollutant species in these streams to expected or actual regulatory/permit limits. An interest group will be formed as part of this project to help power companies learn from the experiences of others as they address near-term operations of wastewater treatment systems.
Particulate and Opacity Control - Program 76

Program Overview

Program Description

Coal- and oil-fired power plants face increasing challenges in meeting emission limits for particulate matter as a result of the March 16, 2011, proposal by the U. S. Environmental Protection Agency (EPA) of Maximum Achievable Control Technology (MACT) standards for hazardous air pollutant (HAPS) emissions from electric generating units (EGUs). These limits, when finalized, will challenge power plants' ability to meet the requirements for both filterable and condensable particulate matter (FPM and CPM); they are proposed to be very stringent, because they are intended to serve as surrogates for nonmercury hazardous trace metals — FPM for the solid species and CPM for any condensable hazardous trace metals, such as selenium. Further, the proposed rules encourage the use of activated carbon injection for mercury and dry alkaline injection (calcium- or sodium-based) for acid gases and SO₃ (to avoid a blue plume or sulfuric acid fallout), increasing loading into the particulate controls. For electrostatic precipitators (ESP’s), the added solids loading, coupled with reduced SO₃ concentrations, make it difficult for them to capture particulates; in baghouses, these conditions may lead to corrosion, blinding, and premature bag failures. The increasing drive for fuel flexibility (including increased deployment of higher-sulfur coal following installations of FGD systems) and biomass co-firing further challenge particulate controls, especially for aging or marginal units.

The Electric Power Research Institute’s (EPRI’s) Particulate and Opacity Control program (Program 76) seeks or develops and evaluates emerging technologies that economically satisfy increasingly stringent particulate emission and opacity limits under a variety of operating conditions, including changes in ash properties and loadings, fuel sulfur content, and SO₃ sorbent use.

Research Value

EPRI searches for, develops, and demonstrates particulate (FPM and CPM) control technologies that can achieve members’ performance goals for complying with the final MACT standards. High priority is given to cost considerations; for existing plants with ESPs, to reduce their risks of early retirement; for new or existing plants with baghouses, to minimize operations and maintenance (O&M) costs. Members of this program can use the results of this R&D to achieve:

- Savings of as much as $50–$150/kW by avoiding ESP replacement with a baghouse or supplemented by a TOXECON™ or wet ESP retrofit to meet the eventual MACT standards;
- Savings in avoided replacement power costs due to opacity-driven derates;
- Extended bag life and lower pressure drop through better fabrics for baghouses;
- Continued ash sales and reduced reagent costs if operational modifications, together with optimized alkali injection systems, can reduce the quantity of alkali injected for SO₃ control;
- Improved effectiveness of activated carbon mercury control through alternatives to SO₃ flue gas conditioning for high particulate matter (PM) capture in ESPs; and
- Improved baghouse performance through better O&M practices.

Approach

Projects conceive of, or find and demonstrate, least-cost upgrades for meeting the increasing particulate (FPM and CPM) control challenges (lower emission limits and loss of startup/shutdown/malfunction exemptions) imposed by the proposed MACT standards, Title V permits, and other regulatory actions. This work also addresses upgrades needed to counter the potential impacts of changed particulate properties on ESP or baghouse performance due to fuel switching, biomass cofiring, or sorbent injection. The R&D includes:
ESP upgrades for compliance with increasingly stringent emission limits, undersized units, or units with
difficult-to-capture fly ash. Upgrades may include development and demonstration of advanced power
supplies, flow modifications, and novel ESP technologies that counter the effects of high-resistivity ash,
sodium depletion in hot-side ESPs, rapping losses, and changed ash properties. These property changes
are expected to be driven by carbon injection for mercury control and alkali injection for SO3, acid gas,
and, possibly, selenium control.

Research to optimize baghouse performance for all fly ash develops methods to extend bag life, reduce
pressure drop, avoid “cleaning puffs,” and detect leaks, all irrespective of fly ash properties. Recognizing
the recent large increase in number of baghouse installations, this project finds and shares best O&M
practices to maximize bag life and minimize pressure drop.

Robust, least-cost acid emission reduction demonstrations of fuel, combustion, and boiler operation
modifications that could reduce SO3 formation in the boiler; updates on industry experience with SO3
controls; and a Tech Watch for novel mitigation measures.

Accomplishments

EPRI provides power companies with solutions to solid and aerosol particulate emissions that are not available
from equipment suppliers due to small returns on investment or high risk. EPRI tests new commercial offerings
to demonstrate their performance and to assist their developers in improving the products. Recent examples
include:

- Publication of a survey of baghouses installed within the last 10 years, identifying practices adopted to
  minimize O&M costs while meeting stringent emission limits. This was an initial 2010 report, with plans for
  a 2011 deeper-dive report.
- Enhancements to EPRI's ESP performance software, ESPM, to improve prediction accuracy when
  treating flue gas with alkali sorbents or increased carbon content. This program is widely used to
  troubleshoot performance issues, or to predict the impact on particulate emissions/opacity of changing
  fuels or implementing upgrades.
- Preliminary demonstration of extended time between off-line cleaning on hot-side ESP using EPRIswitch.
- Demonstrated ability by end of 2011 of: a) the Rapid Onset Pulse Energization (ROPE) power supply to
  provide high-efficiency collection of high-resistivity fly ash without the need for SO3 flue gas conditioning,
  and b) EPRIswitch with polarity reversal to eliminate the need for sodium conditioning for hot-side ESPs.
  Success in these efforts would not only reduce operation and maintenance (O&M) costs, but also avoid
  the negative effects of SO3 on mercury capture by activated carbon and of the added sodium on the
  salability of the fly ash collected in hot-side ESPs.
- Identification of a flow control design that nearly eliminated ESP hopper re-entrainment of fly ash with
  elevated carbon content in one ESP.
- Reduction of ESP particulate emissions by 40–70% in a novel polishing device, EPRI's PMscreen.
- Lower-pressure-drop baghouse fabrics that retain high particulate collection.

Current Year Activities

The program R&D for 2012 will seek to complete any work still needed to demonstrate the effectiveness of
advanced power supplies (ROPE and EPRIswitch) in achieving collection of high-resistivity ash by cold- or hot-
side ESPs, respectively, without alkali addition. It also will continue to develop PMscreen, a low-cost particulate
polishing system. Other activities will seek and inform members of new fabrics and best-practice baghouse
operations, develop guidelines for upgrading ESPs to meet their new challenges, and enhance the reliability and
reduce the cost of SO3 control. Specific efforts will include:

- Demonstration at 1 MWe scale of PMscreen as a low-cost polishing device (e.g., to counter particulate
  increases due to sorbent injection air pollution controls or to meet more stringent emission limits);
- Search for and testing of new fabrics to simultaneously reduce pressure drop and emissions during
  cleaning while resisting degradation due to sorbent injection. Possible tests of new sorbent-impregnated
  filter media for multipollutant capture;
Demonstration of a combination of low-cost upgrades to be identified and qualified by an engineering study planned to be completed in 2011 that, together, can enable existing cold-side ESPs to support the MACT limits for mercury, other trace metals, and acid gases at existing plants (i.e., can handle the increased particulate loading and more difficult solids while meeting reduced emission limits);

- Demonstration of the ability of computational fluid dynamics (CFD)-designed hopper baffles to reduce ESP performance degradation with high unburned carbon containing ash or injected activated carbon (second site to confirm wide applicability);
- ESPM upgrades that can better predict particulate emissions-opacity with high-frequency power supplies; and
- Determination of the ability to achieve significant SO$_3$ reductions through boiler operational changes or deeper coal cleaning/upgrading via application in full-scale tests.

**Estimated 2012 Program Funding**

$1.8M

**Program Manager**

Anthony Facchiano, 650-855-2494, afacchia@epri.com

## Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P76.001</td>
<td>ESP Upgrades for New Emission Limits, Small Units and/or Difficult Fly Ash</td>
<td>This project will develop low-cost upgrades to ESPs that meet the new challenges of complying with increasingly stringent emission limits, collecting difficult ash, and avoiding emission increases despite higher inlet loadings. Updates to ESPM, EPRI's performance prediction tool, will support these technology developments.</td>
</tr>
<tr>
<td>P76.002</td>
<td>Optimized Baghouse Performance for All Fly Ash</td>
<td>Through O&amp;M guidelines, identification and testing of new fabrics capable of meeting anticipated MACT emission limits, and supporting basic tests of ash/bag material properties, this project will document best practices and develop bag materials that consistently produce lower emissions, longer bag lives, and lower O&amp;M costs.</td>
</tr>
<tr>
<td>P76.003</td>
<td>Robust, Least-Cost Acid Emission Reduction</td>
<td>This project identifies and demonstrates lower-cost and more-reliable SO$_3$/sulfuric acid mitigation strategies, mitigating the impact of a MACT limit on condensables, reducing back-end corrosion, and eliminating blue plumes.</td>
</tr>
</tbody>
</table>
P76.001 ESP Upgrades for New Emission Limits, Small Units and/or Difficult Fly Ash (069166)

Key Research Question

On March 16, 2011, the U.S. EPA proposed MACT standards for electric generating units (EGUs) that will require coal- and oil-fired power plants to meet very stringent limits for filterable and condensable particulate matter (FPM and CPM), and to do so with increased PM loading and difficult-to-capture materials. The PM limits are proposed as surrogates for nonmercury HAPS metals (FPM) and volatiles such as selenium (CPM), while the capture difficulty comes from the injection of activated carbon for mercury control and, potentially, alkaline sorbents for acid gas, SO₃, and selenium reduction.

In addition, many ESPs are too small to meet current emission/opacity limits; are being used to collect a higher-resistivity dust than the design fly ash (i.e., following a switch to Powder River Basin [PRB] coal or after implementation of calcium-based sorbents for SOx reduction); or are hot-side ESPs that continue to experience performance issues. These situations — along with the desire to eliminate SO₃ flue gas conditioning in plants that use activated carbon injection for mercury control (SO₃ interferes with carbon effectiveness in capturing mercury) — will require the upgrade of many ESPs. The industry and public would benefit from lower-cost approaches than adding or replacing the ESP with a baghouse. Several advanced power supplies have the potential to meet this need, as do some alternate flue-gas-conditioning chemicals, but all remain to be proven for a number of applications. Other technologies, such as low-cost polishing devices or elevated ash particle charging current made possible by the use of cooled collecting surfaces, may be competitive and provide better performance than SO₃ conditioning. They merit further development and demonstration.

Power companies constantly face questions about the impact of fuel changes on ESP performance and the benefits of proposed upgrades. To answer these questions on ESP performance, environmental control engineers need a comprehensive, reliable, and accurate computer model. EPRI's ESPM model is such a tool and is effective, but needs updating as more is learned about ESP performance with advanced power supplies, or improvements, or difficult-to-collect ash.

Early adopters of wet ESPs placed behind the flue gas desulfurization (FGD) system have experienced corrosion and could benefit from guidance on material selection and water chemistry management to avoid these issues.

Approach

The key activities proposed for 2012 are:

- **Combinations of ESP upgrades.** In 2011, EPRI is assembling a report on ESP performance improvements that have been or could be realized by combining retrofit of advanced power supplies with a set of other ESP upgrades, such as wide plate spacing, improved flow distribution, and modern discharge electrode designs. The objective is to enable existing ESPs to meet the PM limits inherent in the proposed MACT rule and avoid the costly replacement with a baghouse. In 2012, EPRI will seek host sites to demonstrate two to three of the retrofit combinations identified in the 2011 report.

- **ROPE and EPRIswitch.** Based on results from field trials in 2011, EPRI will seek one to three additional demonstrations of EPRIswitch and Southern Company's ROPE technology, alone or together, at plants burning PRB or injecting calcium sorbents for SOx control. One of these field trials may occur at a hot-side ESP suffering performance degradation due to sodium depletion.

- **Re-entrainment management.** For ESPs experiencing carbon re-entrainment, EPRI will seek an additional site to demonstrate the use of computational fluid dynamics (CFD) models to design flow devices that minimize hopper re-entrainment (even of light carbon particles). The effort will include design, fabrication, and installation of the flow devices, followed by EPRI performance testing.
• **PMscreen.** EPRI will continue to develop its polishing device, PMscreen, focusing on low-cost ways to improve its capture performance to >70% of the remaining PM at the ESP outlet without excessive pressure drop. Approaches being considered include the use of metal and polymer felt screen materials, pre-charging the ash, or locating the device downstream of the FGD (instead of a wet ESP).

Other activities that EPRI may undertake, subject to funding and member priorities, include:

• **ESPM upgrade for advanced power supplies.** With the widespread introduction of high-frequency power supplies, it is important to verify that the electrical performance algorithms in ESPM are being extrapolated correctly to the higher charging levels and collecting processes. Accordingly, EPRI will revisit these first-principles algorithms, update them if needed, and test the results against field data (e.g., at the host sites demonstrating the benefits of a prudently selected combination of upgrades). EPRI expects to identify algorithm changes and incorporate them into ESPM in 2012. Validation, testing, and release of the next version of ESPM would occur in 2013.

• **Cooled plates.** Assuming a successful feasibility study in 2010-11 under the Technology Innovation program, EPRI will begin the process of designing and testing a novel configuration that physically integrates “cool pipes” for charging (high-resistivity) particles with the collection plates, leaving the rest of the plate to operate at a lower current and, therefore, avoid back corona. At a minimum, this approach could be a fallback option in the event that advanced power supplies do not reach their potential.

• **Wet ESPs.** EPRI also may seek additional sites to test the performance and operability of the new generation of wet ESPs located post-flue gas desulfurization (FGD) systems in new plants. This investigation will include work to determine the cause of discharge electrode and other component failures, possibly caused by early corrosion onset in some of the newly installed post-FGD wet ESPs. EPRI will build off its substantial experience with FGD materials of construction and its earlier development of water management guidelines for wet ESPs. Pending experience gained in these applications, EPRI may revisit its earlier concept of converting the last field of a conventional ESP to wet operation, taking advantage of the lessons learned during that earlier work. The most important lessons dealt with management of water flow inside the ESP and, as noted, its chemistry. This revisit will include an assessment of the potential value of using membrane plates instead of metallic ones when converting the last field to wet operation.

All the above-mentioned field tests will require supplemental funding for equipment upgrades and detailed sampling. Program 76 will provide the labor to find and organize the tests as well as provide overall project management.

**Impact**

By having EPRI develop and demonstrate low-cost ESP upgrades or other solutions to increasingly stringent particulate emission limits and issues caused by difficult PM, power companies can:

• Save as much as $15–$25/kW if advanced power supplies, alone or in combination with other low- to moderate-cost upgrades avoid the need for an additional ESP field, or as much as $40–$80/kW if they avoid a polishing baghouse. This could be the difference between running or retiring shoulder units once the MACT compliance date arrives

• Enable the use of sorbent injection for SO₂ control in small or low-capacity-factor plants by avoiding the additional cost of a baghouse.

**How to Apply Results**

Power plant owners and operators will be able to procure and tune EPRIswitch, integrated in the future with ROPE, if needed, to meet their particulate/opacity emission limits at much lower cost than other options. They also will receive information about advanced power supplies and a suite of other low- to moderate-cost upgrades that can make them better able to develop least-cost compliance options for the MACT rule. Similarly, the reports on hopper baffles for ESPs collecting high-carbon fly ash will provide guidance on the design and expected effectiveness of this low-cost upgrade, and those on PMscreen will give engineers the information they
need to decide on the adequacy of this polishing device for their situation. Predicting the benefits of any of these approaches can be done by running ESPM, a model that has been modified over the years to increase its ease of use, robustness, and applicability.

### 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td><strong>Low-Cost ESP Retrofit Devices for New Challenges: MACT limits, Increased PM Loading, High-Carbon Ash, or Biofuels:</strong> This project will provide performance results from sites that have applied one or more of the upgrade technologies investigated by EPRI in 2011 (report due 3Q11). This report is likely to center on combining advanced power supplies (typically high-frequency switch mode) with other upgrade technologies aimed at improving basic performance; addressing PM property changes due to sorbent injection for mercury, acid gases, and condensables (especially SO₃); and reducing re-entrainment (especially carbon).</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>EPRIswitch and Other Advanced Power Supplies for Difficult ESP Applications -- Update:</strong> A separate report on these two novel, pre-commercial advanced power supplies. Update of a 2011 report, with majority of report being new field test results. It will include the benefits of the joint operation of ROPE and EPRIswitch to create a fuel-insensitive ESP, if a host site can be found.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>PMscreen Performance Update:</strong> Test results from pilot and field demonstrations of this PM polishing device — PM emissions, pressure drop, and system durability. This report will include preliminary engineering/economic study of potential commercial applications.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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### Future Year Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>ESPM 6.0:</strong> Update to ESPM 5.0 (a late 2010 product) to include robust treatment of high-frequency power supplies, alone or in combination with other upgrades, and updates as needed for biomass and various sorbents.</td>
<td>09/30/13</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Low-Cost ESP Retrofit Devices for New Challenges: MACT limits, Increased PM Loading, High-Carbon Ash, or Biofuels:</strong> Final report in series, with field test results on a range of technologies and combinations. It will include performance of technologies introduced in 2012-13. More results on units with hopper re-entrainment (especially of activated or unburned carbon) are expected than were available in 2012. Also will, include data on novel technologies, such as cooled-plate ESP for high-resistivity fly ash.</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>EPRIswitch and Other Advanced Power Supplies for Difficult ESP Applications:</strong> Update of 2012 report on field test results at additional sites, especially those with high-resistivity ash (PRB or sorbent injection for SOₓ mitigation) and hot-side ESPs with sodium depletion issues.</td>
<td>12/31/14</td>
<td>Technical Update</td>
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</table>

### P76.002 Optimized Baghouse Performance for All Fly Ash (069167)

#### Key Research Question

Power companies increasingly are turning to baghouses (aka fabric filters) to realize very-low-total particulate matter (PM) emissions independent of fuel properties, and for compliance with the MACT standards (when finalized). For MACT, baghouses offer substantial reductions of trace metals through the capture of fine
particulate; high capture rates of mercury on unburned or activated carbon; and the potential to also capture selenium, sulfuric acid, other acid gases (especially hydrochloric acid [HCl] and hydrofluoric acid [HF]), and any organic gases present in the flue gas via sorbent injection. However, baghouses can experience high-pressure drop after only a few months or years of operation, and this factor imposes an energy penalty on the power plant, a derate, or a cost penalty for frequent bag replacements. Further, it is unclear if current bag materials and baghouse operation practices can routinely meet the ultra-low emission limits being considered by regulatory agencies — e.g., 0.005 to 0.015 lb/MBtu filterable PM in order to meet a MACT total proposed PM (filterable plus condensable) limit of 0.003 lb/MBtu. Additionally, bag materials can fail within 1–3 years of installation, which adds an undesirable cost to the system and runs the risk and expense of forced outages. Research is needed on new bag materials that are stronger, resistant to flue gas species (especially sulfuric acid, chlorine, and bromine), porous enough to avoid undue pressure buildup, and still highly efficient during both normal capture operation and cleaning cycles.

Companies operating or planning to install baghouses also can benefit by learning how other users maximize the performance and minimize the costs of their baghouse operations. A collaborative search for and synthesis of these lessons learned is the most cost-effective way to obtain this knowledge

**Approach**

To make baghouses that are more robust, have lower pressure drop, and offer consistently high-collection efficiency available to power companies, EPRI will pursue three parallel paths: 1) preparation of operation and maintenance (O&M) guidelines for baghouses, based on a synthesis of observations from the 2010–11 surveys and visits to sites with current generation baghouses; 2) continued Tech Watch for new developments by bag material suppliers of fabrics that address collection efficiency, pressure drop, and durability; and 3) asic R&D to determine the tenacity, pressure drop, and chemical impacts of dust cakes that build up on bags. EPRI also will try to conceive, as well as search for, novel ideas that it can suggest to the material suppliers, and then test the samples that suppliers produce.

Based on the surveys and site visits conducted in 2009–11, EPRI will document the lessons learned by the individual baghouse operators and analyze these lessons for trends or common experiences. These findings will form the basis of the guidelines, which will highlight fabric selection for different fuels and back-end temperatures, and startup, shutdown and bag cleaning procedures to minimize excessive pressure drop and premature bag failures (acid attack and blinding). Other topics include:

- Instruments to detect leaks;
- Options to control baghouse cleaning parameters and pressure drop;
- Decision criteria on when to replace bags;
- Special considerations when used with sorbents (activated carbon, alkali); and
- Future opportunities applying novel concepts.

In parallel, EPRI will conduct slipstream pilot or full-scale tests of fabrics and procedures that could enable baghouses to achieve continuous ultra-low PM emissions during both steady operation and cleaning periods, while maintaining acceptable pressure drop and cleaning frequency over a long time period. The slipstream tests will be conducted at scales ranging from EPRI's 40 acfm Pollution Control Tester [PoCT] to a power company-owned 2 MWe system, depending on test needs and equipment availability. Given the anticipated stringency of the final PM MACT limits, EPRI will seek newer bag materials, such as dual-density fabrics, that have lower permeability than today's 7 denier fabrics, but also do not allow penetration of fine ash into the fabric pores. To accelerate the development of the new materials and O&M procedures needed to comply with the final MACT standards, EPRI will conduct research on the mechanisms that control ash behavior on a bag. Chief among these are dust cake tenacity on the bags and the impacts of different sorbents and cleaning procedures on pressure drop. These issues seem to be most prevalent at sites with medium to high SO₃ concentrations in the flue gas being treated by the baghouse.
Impact

Success in addressing the issues identified for baghouses will lead to:

- Ability to meet MACT rules for filterable PM even if the final emission limits are extremely stringent (e.g., if < 0.01 lb/MBtu continuously);
- Increased intervals between bag replacement for challenged baghouses from the current 2–3 years to potentially 4–5 years, at a typical amortized savings of $0.5M/yr for a 500-MW plant (plus reduced downtime);
- Maintaining pressure drop across the baghouse below 5–6 in. H₂O, vs. allowing it to increase, e.g., to 10 in. H₂O, saving as much as $200,000/year or more for a 500-MW plant, or avoiding a derate for a fan-limited unit;
- More compact designs of baghouses, with higher air-to-cloth ratios and online cleaning, saving 10–20% in capital costs;
- Improved baghouse design and operating practices for power plants using multiple sorbents for HAPs control;
- Potential savings that could range from modest to large, depending on the errors avoided by the next wave of installations or the changes in O&M practices adopted by current and future users as a result of learning best practices from the survey; and
- Potential avoidance of emission limit violations by understanding the variability in baghouse emissions.

How to Apply Results

Plant engineers can use the O&M guidelines to improve the performance of their existing baghouses, reduce O&M costs, and avoid potential derates due to opacity excursions. Engineering/procurement staff can use the results to specify the most cost-effective baghouses for their needs, accounting for capital vs. O&M cost tradeoffs. Corporate environmental engineers can gain an understanding of future challenges and possibilities by following the progress of the R&D in novel fabrics. They then can use this understanding to recommend optimal particulate control strategies.

2012 Products

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<tbody>
<tr>
<td>Operations and Maintenance Guidelines for Optimal Baghouse Performance: This project will identify best practices as determined by the 2009–11 surveys and site visits, including experience with different fabric/fuel boiler combinations, startup/shutdown practices, and bag-cleaning practices.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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Future Year Products

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P76.003 Robust, Least-Cost Acid Emission Reduction (101447)

Key Research Question

In addition to ongoing concerns about visible blue plumes caused by sulfuric acid mist and new limits on SO₃ and sulfuric acid emissions, power plants soon may face MACT limits on condensables as a surrogate for selenium. Operators also are worried about boiler impacts due to high SO₃ and sulfuric acid concentrations in the colder section of the air preheater and downstream components. Plants that need to reduce SO₃ emissions currently can only capture SO₃ that has been formed in the boiler by injecting alkali sorbents or adding a wet ESP. As both approaches are expensive, and sorbent injection can have negative side impacts, power plants seek lower-cost approaches such as mitigating the initial formation or enhancing the depletion of SO₃ through modified boiler operations and coal cleaning.

At plants using sorbent injection, operators need guidance on sorbent specification, handling, transport, and injection to maximize sorbent utilization and greatly reduce current maintenance.

Approach

EPRI will conduct a multiprogram effort to reduce SO₃ emissions via combustion controls that minimize formation in the boiler, low SO₂ oxidation catalysts for postcombustion NOx control via selective catalytic reduction (SCR), and optimized alkali injection (for SO₃ capture and/or acid gas control). This work will bring together expertise and resources from Program 71 (Combustion Performance and NOx Control), Program 73 (Postcombustion NOx Control), and Program 75 (Integrated Environmental Controls) to:

- Reduce excess air, a prime contributor to SO₃ formation, without sacrificing CO, SCR outlet NOx, unburned carbon, boiler efficiency, or corrosion. Also, evaluate the ability to reduce catalytic oxidation of SO₂ to SO₃ significantly via enhanced coal cleaning to remove large amounts of iron and sootblowing schedules designed to minimize SO₂ oxidation by deposits on convective pass tubes (Program 71);
- Evaluate suppliers' offerings of low-SO₂ oxidation catalysts for their ability to make a significant difference while retaining their mercury oxidation and NOx reduction capabilities (Program 73);
- Collect data on SO₃ reductions/emissions at sites testing alkali injection for acid gas capture to meet proposed MACT limits. Also, follow the modification of EPRI's on-site sorbent activation process (SAP), initially focusing on activated carbon injection for mercury control, to produce a hydrate on demand (would be lower cost than purchased hydrate and avoids pluggage issues because it is created and transported immediately without aging) (Program 75); and
- Complete the development or assessment and demonstration of robust, low-maintenance alkali sorbent storage, handling, transport, and injection systems, especially for hydrated lime, as well as the design of injection systems that minimize sorbent usage for any given application. Also, continue to track supplier developments and new offerings, evaluating (to the extent the supplier and host plants agree) those that seem promising. (this Program/Project).

EPRI will work with members to select and test the most promising SO₃ minimization strategies at host power plants.

Impact

By finding and demonstrating cost-effective methods to reduce SO₃ concentrations experienced in the post-air preheater region of a coal-fired boiler, this RD&D effort will:

- Minimize back-end corrosion;
- Reduce the potential for derates to avoid opacity violations, which could cost hundreds of thousands of dollars per event in replacement power;
- Lessen or eliminate the concern over the proposed MACT limit on condensables (as a surrogate for selenium);
- Save as much as $1–$2 million/year for a 500-MW plant if it can avoid alkali injection, or a fraction thereof if it can only reduce the amount injected; and
- Reduce nearby touchdowns of sulfuric acid plumes.
How to Apply Results

Engineers can use the results of the proposed studies and field tests to identify the most favorable SO$_3$ reduction strategies for their plants and coals. Working through EPRI, they can access the computer models of SO$_3$ formation/depletion that were developed by Lehigh University and Southern Research Institute and run the models for their power plants and fuels to gain an initial assessment of potential SO$_3$ mitigation strategies. Members also can join the Sulfur Oxides Control Interest Group (SOXIG), a supplemental project that provides a forum for technology exchanges among practitioners.

2012 Products

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<tr>
<td>New Approaches to SO$_3$ Mitigation in Coal-Fired Boilers: Report on pilot and field tests of potential SO$_3$ mitigation and capture tests. It includes performance and O&amp;M experience at commercial installations of alkali injection for SO$_3$ reduction.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>New Approaches to SO$_3$ Mitigation in Coal-Fired Boilers: Update of 2012 report with additional longer-term data from sites included in 2012 report and new results from sites/approaches not studied previously.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Guidelines on SO$_3$ Mitigation in Coal-Fired Boilers: Guidelines for reducing SO$_3$ flue gas concentrations along the flue gas path and at the stack, including strategies to reduce SO$_3$ formation and best practices to control it once formed.</td>
<td>12/31/14</td>
<td>Technical Report</td>
</tr>
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Supplemental Projects

Electrostatic Precipitator (ESP) Performance Optimization (072050)

Background, Objectives, and New Learnings
The U.S. Environmental Protection Agency (EPA) has proposed very stringent MACT standards for coal- and oil-fired power plants for filterable and condensable particulate matter (FPM and CPM). The PM limits are proposed to be used as surrogates for non-mercury hazardous air pollutants (HAPS) metals (FPM) and volatiles, such as selenium (CPM). Many existing electrostatic precipitators (ESPs) cannot meet these limits without significant upgrades.

In 2011, EPRI conducted a study of upgraded ESPs that are able to meet these limits following modifications that included installation of new switch-mode power supplies (SMPS’s), wide-plate spacings, discharge electrode (DE) upgrades, flow-modeldesigned devices, and rapping upgrades. Other 2011 EPRI research included flow control research on a host’s precipitator and cooled-plate charging and collection of ash.

The objective of this project is to apply upgrades on a host’s marginally sized precipitator that implement the various options available, with testing to verify performance improvements.

Project Approach and Summary
The project will select, from host site volunteers, an ESP of relatively small size (100-200 MW with a specific collection area [SCA] of 300 to 400 ft²/kacfm, calculated on the basis of 9-inch gas passes) to be rebuilt using state-of-the-art technologies.

Benefits
Previously available upgrade results come from ESPs to which several improvements were applied simultaneously; therefore, they indicate what can be expected from an ESP when equipped with a particular suite of modifications, but not the benefits from upgrading individual components. Assessing each modification’s contribution to the overall improvement by modeling with EPRI’s electrostatic precipitator model, ESPM 5.0, supplemented by baseline and post-installation testing, will produce new learnings by verifying (to the extent possible) the individual improvement contributions.

Providing certainty of performance improvements for marginally sized ESP’s as they are equipped with various upgrades will allow decision-makers to select least-cost options for meeting more stringent emission limits.
Continuous Emissions Monitoring - Program 77

Program Overview

Program Description

In the United States, consent decrees, state laws, and the proposed federal Maximum Achievable Control Technologies (MACT) standards for coal-fired power plants drive the need for robust, accurate, and certifiable continuous emissions monitors (CEMs) for mercury, particulate matter (PM), acid gases, and potentially selenium. Experience with continuous mercury monitors (CMMs) for mercury, particulate matter (PM), acid gases, and potentially selenium remains limited, and their operation and maintenance (O&M) are labor-intensive. PM monitors are not yet used routinely, and their calibration currently is cumbersome, while hydrochloric acid (HCl) is not measured continuously. Under the United Nations’ Environmental Program, a growing number of countries or regions such as Europe are considering similar regulations and face similar compliance monitoring needs. Of particular interest to a number of power companies are instruments that continuously measure solid (filterable) and aerosol (condensable) PM, acid gases (e.g., HCl, hydrofluoric acid [HF], and hydrogen cyanide [HCN]), and ammonia in post-flue gas desulfurization (FGD) stack conditions. Enabling technology needs for these species include:

- Operation and maintenance practices for mercury CEMs that enable operators to approach the O&M now achieved with criteria pollutant CEMS through harvesting the lessons learned by early CMMs users;
- Sampling techniques that lend themselves to the very low pollutant concentrations that may be required by MACT limits, especially for mercury;
- Acceptable ways to calibrate PM monitors at plants with wet stacks without having to disrupt the operation of the wet SO2 control;
- Droplet monitors to measure condensables; and
- Direct measurement of mass emissions to overcome the uncertainty of indirect measurements as PM characteristics change.

Longer term, to remain competitive, the industry needs advanced, microchip- or laser-based CEMs, which hold the promise of 10–25% of the cost of current technology.

The Electric Power Research Institute’s (EPRI’s) Continuous Emissions Monitoring program (Program 77) develops, enhances, and evaluates CEM systems that measure solids and chemical species of regulatory and operational interest.

Research Value

This R&D helps utilities objectively evaluate and implement monitoring options to achieve their measurement needs using robust, accurate, and easy-to-operate instruments. Benefits include:

- Save months of plant instrument technician and environmental engineer time needed to make newly procured CMMs work;
- Prepare for proposed regulations that, if promulgated as proposed, will require mercury measurements below today’s proven quantitation levels, as well as PM measurements (filterable and condensable) as surrogates for nonmercury metal hazardous air pollutants (HAPs);
- Obtain credible, non-ash-property-dependent particulate mass emission measurements made in the stack to benefit from particulate capture by the SO2 control;
- Ensure that ASME receives the data needed to adopt a digital opacity method for power plant stacks as an objective alternative to human observations;
- Optimize NOx and sulfur trioxide (SO3) control operations, or flue gas conditioning for electrostatic precipitator (ESP) performance, via in situ continuous measurement systems for ammonia (NH3), SO3, and sulfuric acid; and
- Potentially save hundreds of thousands of dollars per stack if advanced “sensors-on-a-chip” are developed and accepted for power plant applications.
Approach

This program promotes the development and validation of accurate, robust, and low-maintenance CEMs for compliance with new reporting requirements. It has a near-term emphasis on continuous particulate mass, HCl, and very low mercury concentrations. Based on similar technologies and skills, the program also develops and validates gas monitoring systems intended for optimizing pollutant control operation. Looking ahead to further cost constraints, it identifies, develops, and demonstrates innovative measurement systems with the potential to significantly reduce CEMs costs in the longer term.

- R&D focusing on improvements in compliance monitoring — the near-term emphasis of this program — provides a forum for dynamic interaction among power companies during the first years of implementing CMMs and particulate mass monitors for all emission levels and stack conditions (especially wet stacks). It assists members with issues, documents lessons learned, and tests upgraded CMMs for accurate measurements at very low mercury concentrations. In addition, it will seek or develop and evaluate instruments to measure HCl (and possibly HF), and will demonstrate the accuracy and reliability of digital opacity measurements as a replacement for human observer approaches. A longer-term goal is to find and demonstrate a method to measure aerosols (droplets) as a means of understanding and monitoring sulfuric acid formation and emissions.

- R&D on monitors for process control continues to identify and conduct field tests of continuous monitors for chemical species, the measurement of which could help in operating air pollution controls. The project will retain its collaboration with EPRI's Post-Combustion NOx Control program (Program 73) to demonstrate in situ NH₃ monitors. It also will develop an understanding of the accuracy of CO₂ measurement at 1% concentration level (for future operations with CO₂ capture).

- EPRI's work on advanced monitors — microsensors, CEMS for hostile environments, and automated diagnostics — will reinvigorate its Tech Watch for new advances in continuous monitors (having not had success with the earlier finds), and conduct proof-of-concept tests if any appear promising.

Accomplishments

EPRI's leadership in identifying and resolving performance and O&M issues with CEMs is recognized by the power industry, CEMs equipment suppliers, and regulatory agencies, especially the EPA. This is demonstrated annually by the successful CEMs User Group meetings organized by EPRI, which attracts strong participation by the U.S. Environmental Protection Agency (EPA), vendors/exhibitors, and users. EPRI's value also has been demonstrated in recent years by a number of EPA decisions on mercury monitors that have relied in part on EPRI findings, as presented to the EPA by industry. Examples include:

- EPA approval of the sorbent trap method for continuous mercury monitoring and use as a reference method;
- EPA approval to use an instrumental reference method in lieu of the complex, costly, slow-turnaround-time Ontario Hydro batch method;
- Accelerated development of National Institute of Standards and Technology (NIST)-traceable calibration procedures for CMMs;
- Determination of CMMs' abilities to measure low mercury concentrations, leading instrument vendors to develop and demonstrate monitors capable of measuring accurately the very low concentrations expected after implementation of MACT standards;
- Proposed methodology for calibrating particulate mass emission monitors that avoids the need to exceed emission limits for other pollutants; and
- Strong positive response by the host power station and instrument suppliers to an EPRI-organized and managed PM monitor troubleshooting and development test platform.

Current Year Activities

The program R&D for 2012 will focus on completing efforts to demonstrate the capabilities of CMMs to measure very low mercury concentrations and to operate with less-intensive staff demands; finding and assessing reliable and accurate CEMs for HCl (and possibly other acid gases); re-visiting the search for methods to measure condensables in wet stacks without artifacts; completing field tests of techniques to calibrate
continuous PM monitors without unusual processes; and enabling the use of digital opacity systems on large stacks. Additional efforts may continue the development and demonstration of continuous in situ, spatial measurements of NH₃ and SO₃ in the boiler back-end for process control and the continuing Tech Watch for concepts that could lead to significantly lower-cost CEMs. Specific efforts will include:

- Development and analysis of data that may still be needed to demonstrate the validity of alternate calibration approaches for continuous PM monitors (e.g., to answer EPA questions)
- Assessing the results of a supplemental project to determine the performance of digital opacity measurements on power plant size stacks, and providing the findings to the ASME committee considering certification of this approach
- Determination of detection and quantitation limits for current CMMs and proof-of-concept tests of potential enhancements that enable accurate measurement at emission concentrations expected from controlled power plants
- Demonstration of any concepts for measuring total particulate mass emissions (filterable and condensable) in both dry and wet stacks
- Evaluation and possible proof-of-concept demonstration of potential CEMS for acid gases

**Estimated 2012 Program Funding**

$1.2M

**Program Manager**

George Offen, 650-855-8942, goffen@epri.com

### Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P77.001</td>
<td>Improvements in Compliance Monitoring</td>
<td>By monitoring field experience with CEMs for proposed MACT-regulated pollutants and testing potential new CEMs for species not currently monitored, EPRI will provide information that power company staff can use to optimize operation of their mercury and PM CEMs and procure/operate CEMs for currently unmeasured species.</td>
</tr>
<tr>
<td>P77.002</td>
<td>Gas Monitoring for Process Control</td>
<td>CEMs capable of accurately measuring NH₃ and SO₃ at levels &lt;5 ppm will be identified and validated for the locations in the flue gas path where these measurements are needed.</td>
</tr>
<tr>
<td>P77.003</td>
<td>Development of Advanced Emission Monitoring Technologies</td>
<td>This project seeks out and determines the technical merit of advanced sensors that promise substantial cost reductions for monitoring the full suite of pollutants and are accurate at projected very low future concentrations, whether to demonstrate compliance with proposed MACT limits (especially for new units) or to fine-tune reagent injection.</td>
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</table>
P77.001 Improvements in Compliance Monitoring (051775)

Key Research Question

The March 16, 2011 proposal by the EPA of its MACT rule for HAPs emissions from electric generating units (EGUs) includes requirements to monitor mercury, total particulate matter (or individual nonmercury HAPs trace metals on an annual basis), and HCl (or SO₂ for units with an SO₂ control). For mercury, the needs are to demonstrate CMMs accuracy and reliability at the very low flue gas concentrations expected upon implementation of the MACT limits, and to reduce the labor intensity of maintaining these instruments. Beyond completing any residual work to demonstrate alternative calibration procedures for continuous filterable PM monitors, a need exists to demonstrate accurate measurement of total PM (filterable plus condensable) in the stack, even in a wet stack (post-FGD). Reliable, accurate HCl monitors must be demonstrated. Given the possibility that EPA may revert to a requirement for direct measurement of selenium in lieu of using condensable PM as a surrogate, EPRI will begin to investigate possible monitors for this species. Finally EPRI's 2011 results from a supplemental project to demonstrate the ability of digital opacity cameras to measure plume opacity accurately on power plant stacks (greater than the current method limitation to 7 feet in diameter) need to be analyzed and provided to its members, the American Society of Mechanical Engineers (ASME), and EPA for their consideration in expanding the ASME method to include these stacks.

Approach

EPRI's approach to facilitating the deployment of the CEMs expected to be required by the final MACT rule will depend on the pollutant, given the different development levels and needs:

Mercury.

1. EPRI will maintain the web-based mercury measurement forum (CMMs and sorbent trap) created in 2008 for members to share their experiences and for EPRI and others to suggest solutions. By tracking the dialogue and contacting members of the program, EPRI will assemble the industry's lessons learned in updates provided to members of the program during the quarterly advisor meetings/webcasts. As needed, EPRI will seek fixes to problems or provide guidelines on how to implement CMMs or sorbent traps on particular applications. EPRI will also seek ways to reduce the labor intensity of operating and maintaining these instruments — e.g., by finding, evaluating, documenting, and sharing with members cases in which power plants have significantly reduced their O&M burdens.

2. Working with Program 59, EPRI will conduct the tests needed to determine the detection and, most importantly, quantitation (DL and QL) limits of the leading mercury monitors. EPRI will encourage vendors that are enhancing their CMMs and sorbent trap analyzers to subject them to tests to determine these low concentration measurement limits, and will share its findings with members and EPA, as appropriate.

Total Particulate Matter (TPM)

3. EPRI will complete its ongoing field evaluation (supplemental project) of PM CEMs to demonstrate their performance and calibration techniques that do not require extraordinary measures (e.g., turning off SO₂ scrubber modules to obtain calibration readings at much higher PM levels). The performance of the several PM CEMs will be reported by a supplemental project. Under the base program, EPRI will synthesize the calibration results and document the findings in a format that industry can use to provide information to the EPA on the use of the alternate procedures demonstrated by this project.

4. EPRI will revisit earlier studies of the performance of monitors for both filterable and condensable PM in a wet stack downstream of an FGD and consider ways to overcome remaining issues — especially for the measurement of condensables.
Acid Gases (i.e., HCl)

5. EPRI has identified a few instruments that promise the capability of monitoring HCl continuously. In 2012, EPRI will look for any additional potential monitors and study the designs, experiences, and validation results provided by each potential supplier. EPRI will identify potential integration issues when implementing acid gas monitoring into existing compliance monitoring systems and demonstrate any required modifications to the sample conditioning/handling process. A test campaign in 2013 (or 2012 if there is enough interest among industry to accelerate this effort via a supplemental project) will verify vendor findings.

Digital Opacity

6. EPRI will synthesize and analyze the results from the 2011 supplemental project aimed at determining the applicability and value of digital opacity measurements as a replacement/complement to human observer readings. The findings will be presented to industry, ASME, and EPA in a manner that can be used by the parties to determine whether and how to expand the current method's applicability beyond its current limitation to stacks with diameters of less than 7 feet.

Impact

By facilitating the sharing of experiences among early adopters of CMMs, power plant operators can avoid noncompliance and over-compliance costs due solely to inaccurate or incorrectly certified CMMs.

Independent, substantive data on the performance of CEMs for the other MACT-regulated pollutants, or those being proposed as surrogates, can help operators demonstrate compliance with the final MACT limits with less uncertainty and risk.

Acceptance by EPA of alternative calibration procedures for PM CEMs can allow power plants to certify their monitors without having to detune or bypass pollutant controls such as SO₂ scrubbers.

How to Apply Results

Plant instrument technicians and plant and corporate environmental compliance engineers can obtain information about CMMs through the EPRI website and staff technical support. They will also be able to compare their operations to best practices documented by EPRI and use the report to determine if improvements to their systems or procedures are warranted.

2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td>Performance of Digital Opacity Monitoring Schemes for Power Plant Stacks: Analysis of findings from supplemental project, documented in a format useful for presentation to ASME and EPA, to inform decisions on allowing digital opacity methods to be used on power plant stacks (&gt; 7 ft. diameter).</td>
<td>08/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Continuous Monitoring of MACT-Regulated Pollutants: Update on field experience with CMMs and lessons learned for high reliability at reduced O&amp;M costs. Includes assessment of detection/quantitation levels for CMMs enhanced to measure very low mercury concentrations. Provides a status report on the capabilities and limitations of mass PM CEMs, with special focus on measuring condensable PM in wet stacks, and on CEMs for HCl.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
Continuous Mercury Measurement Guidelines – Final Report: Final report, with guidance based on up to four years experience, as well as newer developments/advances. Similar to well-known periodic CEMS Guideline updates. 12/31/13 Technical Report

Continuous Monitoring of MACT-Regulated Pollutants: Final report on tests and evaluations of CEMs for filterable PM, condensable PM, and acid gases. Future work may be needed to document lessons learned from early applications and develop mitigations measures for any issues. 12/31/14 Technical Report

P77.002 Gas Monitoring for Process Control (069168)

Key Research Question

Continuous measurement of ammonia (NH₃) and SO₃/sulfuric acid (H₂SO₄) can be used for real-time control of: a) the NH₃ injection grid used in selective catalytic (or non-catalytic) reduction (SCR or SNCR) systems for NOx; and b) the injection of alkali to manage SO₂, and c) the injection of SO₃ to improve electrostatic precipitator performance. In addition, as emission regulations become more strict, power plants are likely to be subject to limits on these species in addition to the criteria and MACT pollutants. The rules may limit these pollutants directly or indirectly as a regulation on condensable PM (CPM); SO₃ and NH₃ are believed to be the major contributors to CPM. Typically, emission regulations are accompanied by requirements for CEMS to demonstrate continuous compliance. CEMS for SO₃ are just beginning to be introduced and need to be demonstrated. Implementation of continuous NH₃ and SO₃ monitoring will require the development of appropriate QA/QC procedures to maintain/verify continuous accuracy of the monitors.

Approach

A few CEMS suppliers recently have announced their development of a continuous SO₃/H₂SO₄ monitor for use in either dry or wet stacks. In 2011, EPRI will try to arrange for field tests of one or two devices that appear to be ready for full-scale, real flue gas. The tests would be conducted, analyzed, and documented in 2012. EPRI will work with the system suppliers to develop QA/QC procedures and equipment necessary to deliver reliable standards for calibration of NH₃ and SO₃ monitors in field applications. Given their relatively early stage of development, these instruments may still need field test time to address issues that will inevitably arise, and EPRI would try to provide the suppliers with the test platform and periodic reference tests as they enhanced their systems (similar to EPRI's earlier approach with mercury CEMS and, in 2011, with PM CEMS). EPRI will continue to provide technical input to the ASTM International committee developing new standard procedures for measuring SO₃ concentrations using the controlled condensate method, with the aim of improving accuracy and consistency.

EPRI will seek opportunities to demonstrate the accuracy of tunable diode lasers (TDL) when used for in-stack measurements in either dry or wet stacks (although NH₃ concentrations are expected to be very low following a wet FGD system). Given the opportunity (host site and resources), this program will collaborate with Program 73 (Post-Combustion NOx Control) to develop ways to measure NH₃ downstream of the SCR. EPRI staff will search for, and demonstrate, methods to overcome interference by the particulate in the flue gas at this location. If warranted, based on results published by others, EPRI also may revisit the possibility of using differential optical absorption spectroscopy (DOAS) to determine if successful approaches have been found to overcome a potential interference by SO₂.
Impact

- Successful demonstration of an NH₃ monitor accurate at emission levels consistent with the regulatory limits will prevent exceedances or costly over-control.
- Accurate measurement of SO₃ concentrations can minimize the consumption (and cost) of reagents used for SO₃ control or, in the case of SO₃ injection for ESP performance, the amount of SO₃ injected.
- The ability to monitor SO₃ and/or NH₃ continuously could make it easier to demonstrate compliance with the MACT rules for condensables than the approach proposed by EPA on March 16, 2011.

How to Apply Results

Engineers responsible for CEMS procurement and compliant operation can use the performance data generated under this project to determine if instruments are ready for commercial operation, how they need to be installed and operated, and what to require in a bid package for such devices.

2012 Products

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<tr>
<td>Ammonia and SO3 Monitors for Ultra-low Emission Levels -- Technology Readiness Report: Field test results from two to three sites with very low NH₃ emissions and assessment of the technology readiness of the monitor. Field test results from one to two sites of continuous, post-particulate control SO₃ monitors for process control and potential compliance.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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P77.003 Development of Advanced Emission Monitoring Technologies (072051)

Key Research Question

As emission limits become more strict, measurement equipment will be challenged to monitor more species and at low concentrations. Significant cost advantages are expected if new multicomponent, lower-detection-level monitoring systems can be developed. Recent advances in microchip and nanotechnology offer the promise of drastic reductions in CEMs costs, both through miniaturization and multipollutant measurement capabilities in a single system, as well as greater sensitivity. However, given the small market size of the power industry relative to other industries that use microsensors, developers are not devoting resources to flue gas measurements; hence, the power industry needs to lead the effort to gain the benefits. A substantial portion of the investment in continuous emission monitoring systems is related to sample acquisition and delivery to the appropriate analyzers. EPRI will seek innovative approaches to sample acquisition and delivery that provide alternatives to the current dilution extractive systems. Potential benefits might include reductions in hardware, validation requirements, and opportunities for advanced sensor technologies.
Approach
With the appearance of a few new developers of quantum cascade laser (QCL) technology for low concentration measurements of gaseous species — an advanced technology with promise for significant cost savings in the future — EPRI will resume its efforts to demonstrate it. Pending developer cooperation and the availability of a host site, EPRI will conduct field tests on real power plant flue gas and compare the measurements to reference methods. Innovative approaches to sample conditioning will be investigated in both laboratory and field settings to determine the potential for further enhancement of CEM system designs.

EPRI will continue its Tech Watch for new CEMS developments — emerging technologies or field-tested devices used in other applications that may be applicable to stack monitoring or process control. EPRI also will follow EPA's regulatory calendar in order to stay abreast of any new requirements or technology determinations. The findings will be documented and test plans prepared for the members for any promising new approaches.

Impact
Successful deployment of emerging measurement technologies could lower capital and operating costs and improve accuracy at the anticipated future lower emission limits (P77.001). It could also reduce the costs of measurements for process control (P77.002).

Advanced knowledge of potential new monitoring requirements will give the industry time to prepare, lessening the chances of being saddled with unnecessarily costly instruments.

How to Apply Results
Planners considering the next round of CEMs replacements will be able to anticipate significantly advanced monitors with greater confidence.

2012 Products

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<td>Advanced Sensors for Continuous Flue Gas Species Measurements:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Identification (through Tech Watch) and engineering assessment of microsensors that might be applicable for use in CEMS or for flue gas species monitoring for automated process control. Lab or field test results if such sensors are found.</td>
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<tr>
<td>Advanced Sensors for Continuous Flue Gas Species Measurements -- Update 2014:</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Update of 2012 report on microsensors that might be applicable for use in CEMS or for flue gas species monitoring for automated process control. Tech Watch findings and laboratory or field test results if promising sensors are found.</td>
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Supplemental Projects

Demonstration of Alternative PM CEMs Calibration at Multiple Sites (072052)

Background, Objectives, and New Learnings
Some electric generating units (EGUs) are required to monitor particulate matter (PM) emissions using continuous emissions monitoring systems (CEMS). Many more expect they will have to install PM monitors under proposed MACT rules. Currently, simultaneous EPA manual reference method tests (EPA Reference Method 5) must be used to calibrate and audit these PM CEMS, following EPA Performance Specification 11 guidelines (PS-11). These audits not only are difficult, time-consuming, and expensive to perform, but they are particularly onerous, because the method requires the EGU to modify plant operating controls and procedures to achieve a range of PM stack concentrations that is adequate to calibrate the CEMS. There is a clear need for better methods to calibrate and audit these PM CEMS, providing sufficient concentration range while eliminating complicated modifications to plant operations.

Under other EPRI-sponsored efforts, Cooper Environmental Services (CES) has optimized a quantitative aerosol generator (QAG) to produce precisely known quantities of PM aerosols in the laboratory. The applicability of the QAG for PM CEMS calibration has been evaluated using laboratory and field tests.

This project will support field testing of the QAG unit at different sites and stack conditions, and represents new learning for calibrating PM monitoring equipment without increasing emissions over a range of plant sites and stack monitoring conditions.

Project Approach and Summary
This project will support field testing of the QAG unit at different sites and stack conditions. The QAG system will be validated using the EPA PS-11 procedures as currently required. By validating the QAG calibration approach on multiple units and stack conditions, the project will provide implementation guidance and performance information for users to propose as an alternative to utilizing the full PS-11 procedure in future PM CEMS certifications.

Benefits
The successful demonstration of this method will provide more robust calibrations of PM monitors over a wider range of monitoring types and stack conditions, while minimizing the need to recalibrate due to out-of-range instrument readings. The public will benefit through more accurate demonstrations by power plants that they remain in compliance with their PM limits.
Developing Digital Opacity Methodology for Large Diameter Stacks (072053)

Background, Objectives, and New Learnings

The ASTM D-22.03 committee recently approved a test method (D7520-09) that uses digital cameras and associated software to make stack opacity determinations. The method is restricted to stacks less than 7 feet in diameter, primarily because it has never been evaluated on larger stacks. The method was developed to mimic EPA Method 9, and does not take advantage of the technology offered by the digital cameras available today but rather uses the same acceptance criteria applied to human observers qualified via “smoke school.”

This project will focus on developing the data suitable for applying the precision and bias calculations mandated by ASTM, using a standard against which all method measurements are compared. The project will use the available software with multiple digital cameras compared to a certified transmissometer at a “smoke generator” used for Method 9 training, as well as field testing on large-diameter stacks with certified opacity monitors.

The data generated will cover the full range required by Method 9, but will concentrate on the low 0–20% and 20–40% opacity ranges more typical of electric generating units with large stack diameters. Field studies will cover both wet and dry stack applications.

The project will be conducted with advice and consultation from the ASTM D-22.03 committee on data and procedure needs to support future modification of the current Digital Opacity Method.

Project Approach and Summary

This project will establish a methodology for using digital camera technology for remote measurement of opacity in largediameter stacks. The project will be conducted in two phases. The first phase will establish the “calibration” of the digital camera(s) with respect to a certified transmissometer associated with an accredited “smoke school.” This calibration phase will establish the precision and bias data required by ASTM. The second phase will be a field validation of the method on both wet and dry stacks.

Benefits

The proposed project will provide a more reliable opacity method for large stacks, eliminating much of the variability and inconsistency of current Method 9 readings. The resulting revision to the ASTM D-7520-09 Digital Opacity Method could be a major step forward in opacity observations, removing subjectivity and providing a documented record of opacity events.
Coal Combustion Product Use - Program 78

Program Overview

Program Description

Disposal of coal combustion products (CCPs) is an expense, a potential long-term liability, and, in many locations, difficult due to limited site availability or environmental opposition. Other challenges include increasingly stringent regulations on ash disposal, possible prohibition against the use of CCPs in "unencapsulated" civil engineering applications (e.g., road base); questions about the usability of ash from power plants adding certain gaseous pollutant controls (especially sorbent or chemical injection), cofiring biomass with coal, or deploying integrated gasification combined cycle (IGCC) power systems; and new public concerns over the health and environmental safety of products that contain ash. At the same time, the doubling of installed SO₂ scrubber capacity is increasing the production of flue gas desulfurization (FGD) gypsum beyond the needs of the wallboard manufacturers, giving rise to searches for effective and environmentally acceptable new uses. In parallel, the growing installation of spray dryer SO₂ controls and fluidized-bed boilers will produce volumes of solid products that will require large-scale, accepted uses.

The Electric Power Research Institute’s (EPRI’s) Coal Combustion Product Use program (Program 78) builds on years of investigation into sustaining the use and value of CCPs, despite property changes due to the application of gaseous air pollutant controls. It also seeks new uses for current CCPs and markets for the new CCPs from biomass cofiring, IGCCs, and plants equipped with spray dryers. In light of regulatory uncertainty and in response to increased scrutiny of CCP management, the focus in 2012 will be on the testing of products made with CCPs to ensure acceptable environmental performance in typical applications; life-cycle assessment to quantify benefits and costs of CCP use; and increased communication of CCP use information to funders, end-users, regulators, and the public. Additional projects may be proposed during the year if regulatory direction becomes clearer.

Research Value

The CCP Use Program demonstrates that these products can be used beneficially and in greater quantities, even in the face of property changes due to upstream air pollution controls or different fuels or generation technologies. The program’s R&D enables members to:

- Avoid disposal costs for CCPs, which range from $5 to $60/ton and require extensive staff and management time to find and permit a landfill;
- Retain or earn new revenue by selling products to ready-mix concrete plants, wallboard manufacturers, agricultural soil amendment distributors, roadway builders, and others, typically for $10–$20/ton, although prices can be as high as $60/ton. This includes:
  - Products sold today, such as flyash and FGD gypsum
  - Products not currently sold in quantity, such as spray dryer or fluidized-bed combustion (FBC) solid products, and ash containing activated carbon, elevated sodium levels, or biomass products of combustion;
- Anticipate and resolve issues that may be barriers to the use of CCPs from biomass cofiring and IGCCs; and
- Communicate the engineering and environmental aspects of CCP uses, both existing and new.

Approach

The program collaborates with organizations such as the American Coal Ash Association (ACAA) to provide information to state government agencies and engineers on the environmental and engineering uses of CCPs, and with the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Agriculture (USDA) to address significant barriers to CCP use at a national level. As issues arise with materials that use CCPs, this program researches the root cause of the problems and develops solutions, including:
• Research for environmental testing and assessing risks of products containing CCPs involves evaluations of the potential human health and ecological risks posed by products containing CCPs. These evaluations may include topics such as off-gassing of volatile elements in building applications; potential exposures from a variety of road base applications; and direct contact exposure by the public to CCP-containing products. Integral to this effort will be data on comparative risks posed by products when manufactured with traditional feed materials.

• The outreach and communication project prepares briefs and makes public presentations, as needed or requested by members, to convey the scientific basis for various CCP use applications. It also fills technical data gaps in development of science-based regulations and standards, including working with trade groups and standards organizations. The project maintains a Tech Watch for new issues limiting current or potentially expanded use of CCPs and informs the members.

Accomplishments

The CCP Use program is recognized in the electricity industry as an authoritative source for up-to-date information on the benefits and environmental aspects of using CCPs in commerce. Recent examples of value provided include:

• Documented, in a series of quick-turnaround reports, the environmental, resource, and financial benefits of using CCPs instead of raw materials; the chemical similarity between CCPs and natural or other large-volume materials commonly treated as solid waste (i.e., not hazardous); the substantially lower risk from CCP disposal at sites built in the last 30 years than at sites categorized as "damage cases" by EPA, which had been constructed earlier with fewer protections; and the potential costs of regulating CCPs as hazardous wastes;

• Demonstrated that no significant mercury is released during concrete curing, or by leaching of demolished and crushed concrete, when fly ash containing mercury is used in the manufacture of the concrete;

• Quantified the amount of mercury released by one type of wallboard manufacturing process when FGD gypsum containing mercury is used in the manufacture of the concrete;

• Demonstrated that concrete cracking due to reactions between cement and aggregate could be mitigated by replacing some of the cement with Class F ash; provided evidence that, for many aggregates, cracking could be mitigated by replacing large volumes of cement with Class C ash or ternary blends;

• Organized a collaborative including utilities, government agencies, industry, and academia to demonstrate the value and environmental acceptability of using FGD gypsum and other FGD solids in agricultural applications; and

• Identified potential uses for spray dryer and FBC solid products based on engineering properties and European experience.

Current Year Activities

The program R&D for 2012 will focus on continuing demonstrations of process benefits and environmental acceptability of CCP use, with greater emphasis on the latter, determining the impact on CCP use of air pollution controls, and seeking/evaluating potential uses for new CCPs. Specific efforts will include:

• Initiation of a multiyear project to determine the health risks of products that contain fly ash, especially products that individuals contact or to which they are routinely exposed;

• Identification of changes in fly ash characteristics from biomass cofiring and implications on use of these products;

• Initiation of a multiyear effort to demonstrate the environmental acceptability of ash use in road base; and

• Research to develop one or two potentially large beneficial uses of spray dryer absorber products, including spray dryer/baghouse installations with fly ash pre-collection.

Estimated 2012 Program Funding

$0.4M
Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P78.001</td>
<td>Environmental Testing and Assessing Risks of Products Containing CCPs</td>
<td>Development of a framework for laboratory and field testing of products to assess and communicate the relative risks and benefits posed by products containing CCPs.</td>
</tr>
<tr>
<td>P78.002</td>
<td>Outreach and Communication</td>
<td>Develop and present information that provides regulators and potential users of CCPs with the environmental footprint and resource/energy/cost savings of CCP use relative to other options.</td>
</tr>
</tbody>
</table>

P78.001 Environmental Testing and Assessing Risks of Products Containing CCPs (046746)

Key Research Question

The EPA proposal to regulate disposal of CCPs has also led to increased scrutiny of the environmental performance of CCP beneficial use applications, for "encapsulated" as well as "unencapsulated" uses. A recent investigation report by the Inspector General's office harshly criticized EPA for inadequate demonstration of the environmental safety of CCPs when used in essentially all common applications. The public and some state agencies have begun to question the suitability of products containing CCPs for use in common construction applications due primarily to environmental concerns. As a result, power companies and end-users are concerned with potential liability associated with products containing CCPs.

Research under this project will focus on developing test data and risk assessment information to address these questions and quantitatively evaluate the potential for environmental risks. Although some applications, such as the use of fly ash in concrete, have been commonly employed for decades without apparent problems, the heightened regulatory and public concerns are driving a critical need to develop data to systematically document that these products do not pose an unreasonable risk to public.

Approach

EPRI will perform evaluations of the potential human health and ecological risks posed by products containing CCPs. These evaluations may include topics such as leaching of disposed concrete and wallboard, off-gassing of volatile elements in building applications, hydrogen sulfide (H2S) generation in wallboard use and disposal, potential exposures from a variety of road base applications, and direct contact exposure by the public to CCP-containing products. Integral to this effort will be comparative risks posed by products when manufactured with traditional feed materials, or other products with which people routinely come in contact.

This project will initiate work on a broad range of products, focusing on the largest and most common applications first. Leaching tests will include the new EPA Leaching Environmental Assessment Framework (LEAF) protocol, refined for the specific applications and calibrated against field data. Test information will be used along with potential exposure scenarios to assess the potential risks associated with these products.

In some cases, this work will be designed in conjunction with more extensive field testing, possibly done in supplemental projects. Examples include the use of ash in road base applications and the use of FGD gypsum and spray dryer absorber products in agricultural applications. The field test data can greatly enhance the understanding of the laboratory results, as well as allow development of more realistic exposure scenarios. Leaching and field testing work and risk analysis will be coordinated with research on CCP Environmental Issues in Program 49 (Coal Combustion Products – Environmental Issues).
As part of this research, work will continue on the changes in characteristics of the CCPs themselves as new emissions controls such as sorbent injection, and fuel blends such as cofiring biomass, are employed. Biomass work will be coordinated with Program 84 (Renewable Generation) and Program 76 (Particulate and Opacity Control). In future years, the characterization research may be extended to include the new generation of products from IGCC units.

Impact

Information on the environmental performance of products containing CCPs, as well as comparisons to relative risks of competing materials, is necessary to enable regulators, end-users, and the public to make informed decisions on the safety of using products that contain CCPs in various applications. This project helps power plants:

- Develop environmentally sustainable practices for CCP management;
- Increase CCP use and reduce disposal costs and liabilities, which currently can be $10-60/ton ash and may be much higher if EPA designates CCPs as hazardous; and
- Retain or earn new revenues from sale of CCPs, which can vary from a net $0 to more than $60/ton ash.

How to Apply Results

Power company CCP managers and their CCP marketers can use the test data and supporting analyses to plan continued use of their CCPs and identify new uses consistent with local market and transportation conditions. They can use the same information to inform existing and potential end-users, as well as regulators and the public, of the value of these uses.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCP Product Characterization and Risk Assessment: Results of laboratory and field characterization tests of selected CCP-based products to determine the potential for release of harmful substances in common use environments. Comparative data for products with and without CCPs. Evaluation of potential risks associated with use of CCPs in these products.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>

Future Year Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCP Product Characterization and Risk Assessment: Follow-on to 2012 report with assessments of additional products manufactured using CCPs.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>CCP Product Characterization and Risk Assessment: Anticipated last report in this series of risk assessments of products manufactured using CCPs.</td>
<td>12/31/14</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>
P78.002 Outreach and Communication (052539)

**Key Research Question**

There are many diverse uses for CCPs, and many stakeholders in their use, including electricity generators, marketers, regulatory agencies, transportation departments, ready-mix companies, geotechnical engineers, and the public. Concise communication of research results on the engineering value and environmental acceptability of CCP applications to all of these stakeholders is critical to their acceptance. Outreach efforts — preparation of technical briefs and issue papers, conference attendance and presentations, site visits, and regulatory activities — facilitate two-way communication of technical information between EPRI and its members and the stakeholder community.

**Approach**

Prepare technical briefs and similar short communications as needed to convey the scientific bases for various CCP use applications. Present papers and attend meetings to exchange information on the latest research, demonstration of applications and their environmental footprint, and new technologies. Support member requests for assistance with technical information for federal, state, or local agencies. Identify and respond to technical data gaps to support development of science-based regulations. Work with trade groups, such as the American Coal Ash Association, and standards organizations, such as ASTM, to provide technical support on CCP use issues. Evaluate life-cycle assessments that quantify the benefits of using CCPs versus virgin construction materials. Maintain a Tech Watch for new issues limiting current or potentially expanded use of CCPs.

**Impact**

EPRI’s outreach efforts convey complex technical information to program funders for their use in evaluating management options, and to the wider audience of end-users, regulators, and the public with potential interests in the use of CCPs. The benefits are increased understanding of CCP uses in applications with demonstrated engineering and environmental benefits, leading to increased use opportunities and decreased disposal costs.

**How to Apply Results**

Environmental compliance and CCP management staff can use the technical briefs to inform the public, potential CCP users, and regulators about the environmental, technical, and financial aspects of CCP use.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCP Use Communication: Annual set of technical briefs and resources informing members and the public of the environmental footprint and savings of using CCPs, focused on issues of most interest during the year.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
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</table>

**Future Year Products**

<table>
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<td>CCP Use Communication: Annual set of technical briefs and resources informing members and the public of the environmental footprint and savings of using CCPs, focused on issues of most interest during the year.</td>
<td>12/31/14</td>
<td>Technical Resource</td>
</tr>
</tbody>
</table>
Supplemental Projects

Development and Demonstration of High Volume Uses for Spray Dryer Absorber Solid Products (072054)

Background, Objectives, and New Learnings

Spray dryer absorber (SDA) systems comprise about 10 to 15% of the flue gas desulfurization systems at coal-fired power plants in the U.S. In 2009, these systems produced 5 to 10 million tons of SDA byproduct, a mixture of calcium sulfite/sulfate, unreacted reagent, and fly ash. Less than 5% of this material is used, and the remaining amount is disposed of in landfills. Siting restrictions and public opposition are making it increasingly difficult to develop landfills, and costs of disposal are expected to increase significantly when the U.S. Environmental Protection Agency (EPA) finalizes national regulations for coal combustion product (CCP) disposal.

The purpose of this project is to research and develop use applications for SDA by-products. A literature review in 2007 (EPRI report 1014915) and follow-up characterization testing in 2009 (EPRI report 1017580) provide the basis for more targeted research to develop economically viable and environmentally safe uses. Those reports evaluated SDA systems that do not have separate fly ash capture upstream of the absorber, the most common configuration in the U.S. today. The most promising uses identified for this by-product included cementitious products and structural fill/mine fill applications.

Newer systems constructed in the last few years employ separate collection of fly ash prior to the absorber, resulting in a by-product composed of calcium sulfite/sulfate and unreacted reagent. This material also may be suitable for use in agriculture, along with a wide variety of uses currently employed in Europe, where this SDA configuration has been more commonly used.

Project Approach and Summary

EPRI will work with the project participants to identify the most promising applications for research. One or two research projects will be initiated in the first year, depending on funding. The projects are expected to be selected from a group that includes:

- Concrete
- Manufactured aggregates
- Geotechnical fills
- Agriculture

Depending on priorities established by participants and funding levels, additional projects may be initiated in future years.

Projects may consist of laboratory work, field demonstration, or a combination of the two. Concrete and aggregate would probably be considered "encapsulated" or "bound" uses, and therefore may be exempt from national CCP regulations. Research on these uses likely would be predominantly laboratory work to assess and optimize engineering properties. Geotechnical fills and agriculture applications likely would be considered "unencapsulated," and their regulatory status is less certain. Research in these areas would rely more heavily on field studies, and include a larger component of environmental performance testing.

Benefits

Nearly all SDA by-products in the U.S. currently are disposed of in landfills. Under the nonhazardous waste alternative in the U.S. EPA proposal, disposal costs for SDA byproducts could exceed a quarter of a billion dollars annually. Use of the material reduces disposal costs, conserves valuable landfill space, replaces use of natural resources, and can provide savings in energy use, water use, and carbon footprint.
Demonstration of High Volume Uses of Ash in Road Applications (072055)

Background, Objectives, and New Learnings
In 2009, the utility industry produced about 136 million tons of coal combustion products (CCPs). The geotechnical properties of CCPs, especially fly ash and bottom ash, make them ideally suited for a variety of road construction applications. However, only about 2 million tons (1.5%) were used in road-construction-related applications in 2009.

The potential market for CCPs in roadway applications is large, on the order of tens of millions of tons per year. There are currently about 5 million linear miles of highway in the United States, many in need of repair or replacement. The American Society of Civil Engineers (ASCE) 2009 Annual Report Card on Infrastructure gave roads a D-, the lowest of any category; it estimates that at least one-third of major roads are in poor or mediocre condition. The U.S. currently spends $70.3 billion per year on highway improvements, less than half of what ASCE estimates is needed to substantially improve conditions.

The recent proposal by the U.S. Environmental Protection Agency (EPA) to establish national regulations for CCP management may exempt "encapsulated" uses. But these uses are not clearly defined, and many of the road construction applications fall in a hazy area between known encapsulated uses, such as concrete, and unencapsulated uses, such as structural fills. Although CCPs are widely accepted for their engineering properties in some of these applications, environmental performance will require additional documentation to address the concerns of regulators, end-users, and the public.

Project Approach and Summary
This project is designed to perform RD&D on the use of CCPs in road construction applications. These applications may include:

- Soil stabilization,
- Road base,
- Pavement recycling/full-depth reclamation,
- Use of ash in asphalt,
- Road embankments

Two major advantages of these applications are that they can use ash that is not suitable for use in concrete, and some applications almost certainly would meet the definition of encapsulated or bound uses.

Projects may include documentation of case histories, economics, and engineering performance. Life-cycle analyses would quantify, on a common basis, all the costs and benefits, such as increased durability and savings in virgin materials, energy consumption, and cost. Laboratory and field projects would focus on the engineering properties and environmental performance for specific applications.

Project participants would drive selection of research topics and project types. Web conferences, meetings, and possibly site visits would be used to communicate research plans and results to all participants.

Benefits
CCPs are significantly underutilized in roadway construction, despite general agreement that they provide superior performance at lower cost in many applications. It is conservatively estimated that use in these applications could increase by 5 to 10 times the current rate, yielding substantial societal benefits in infrastructure repair, as well as reduced disposal costs for the power company sources of the ash. These applications can serve to reduce disposal costs and conserve valuable landfill space, as well as replace use of natural resources and can provide savings in energy use, water use, and carbon footprint.
Power Technology, Market Analysis and Risk - Program 178

Program Overview

Program Description

Electric utilities face very large investment decisions with very long-term consequences. However, tremendous uncertainties exist in many dimensions, including technology development, regulations, loads, fuel markets, and electricity markets. These uncertainties are extensively interrelated and potentially very disruptive to planning for an optimum asset mix. Analysis and integration of the vast amount of available information, opinion, and uncertainty related to the above areas are critical to a successful technology strategy. Furthermore, increased public scrutiny and media coverage of the electric sector require objective, credible technical information, and analysis to inform regulators, policymakers, and the media.

Aging infrastructures, long-term growth in electricity demand, a competitive and increasingly complex marketplace, and changing regulatory environment require that optimal technology development and investment strategies incorporate tools and data that enable an integrated understanding of technology options, costs, and market drivers. This diverse set of resources should include:

- Comprehensive, credible, and up-to-date data and analyses of:
  - Technology costs and performance
  - Forthcoming changes in the generation fleet
  - Fuel markets and infrastructures
- Consistent analysis methodologies and tools for:
  - Incorporating technology costs and performance in asset planning
  - Evaluating portfolio strategies (e.g., retire/retrofit/replace) under unprecedented change
  - Anticipating new regimes in price/cost volatilities and their inter-relationships
  - Optimizing transactions (e.g., fuel, power) to better manage risk

Research Value

EPRI’s Power Technology, Market Analysis and Risk program (Program 178) integrates three vital areas of research: technology assessments, power/fuel market analyses, and methods for managing market/enterprise risk. Key examples include the annual Technical Assessment Guide TAG®, an ongoing series of reports assessing coal and gas markets, and integrated analysis of generation asset portfolio strategies under diverse scenarios. Together, they provide:

- Comprehensive data, methodologies, and tools, resulting in a sound technical basis for technology planning, investments, and market strategies;
- Complementary research to the other areas (e.g., fuel markets and volatility analysis can enhance quality of technology cost estimates); and
- Collaborative research and development, which allows participants to get the maximum value from EPRI’s industrywide data and analysis when making key technology and business decisions.

Approach

- Technical reports capture industrywide cost and market data, establish reference values, offer new and improved analysis methods, and provide insights into key trends. An example is the Technical Assessment Guide TAG®. Another example is gauging the impact of gas shales.
- Algorithm development and software tools provide customizable and flexible application of accepted methodologies to analysis of technology costs, asset portfolio planning, market risk, and price/cost volatility. Flagship products include TAGWeb® and the Energy Book System (EBS).
Meetings and webinars, such as the annual EPRI/EEI conference on Power Technology, Fuel Supply and Market Risk. Critical technology cost and market data inform EPRI’s public domain research conducted under the Energy Technology Assessment Center (ETAC).

**Accomplishments**

- EPRI's Technical Assessment Guide (TAG®) is recognized as an authoritative source for up-to-date technology information. It is well-accepted by regulators, and is sought after as a critical resource by both U.S. and international agencies and researchers.
- EPRI's fuel and industry markets research continues to expand understanding of the link between power plant project developments and domestic and global fuel markets; changing assessments of fuel supply and availability; and impacts of changes in infrastructures critical to the fuel supply chain. The most recent accomplishment is an extensive analysis of “generation shifts,” e.g., displacement of coal by natural gas, and the prognosis for its continuation.
- EPRI’s power markets and risk research provides updates on existing forecasting and risk mitigation approaches, as well as methods for addressing emerging risks. This research area includes the "Energy Book System" (EBS) for asset valuation and risk management.
- Innovative, scenario-based analysis of generation asset portfolio planning, integrating portfolio financial risk analysis tools.

**Current Year Activities**

The Power Technology and Market Risk program in 2012 will focus on key issues and strategies that inform participants' management of asset portfolios.

- Existing data sets, tools, and services to participants will be maintained and enhanced, particularly in the TAG® and power markets and risk areas.
- Annual deliverables such as the TAG® technology report and the Annual EPRI-EEI Power & Fuel Supply Seminar will be provided.
- EPRI will continue to feature TAG® prominently as a basis for many of its public-domain research activities.
- Emerging issues with high uncertainty and complexity will be investigated.
- Generation asset portfolio management strategies focus on retire/retrofit decisions and critical uncertainties. Related impacts on cycling/provision of load-following services also will first be examined in a supplemental study this year.
- Fuel, electricity, and emissions market effects on asset valuation and risk will be explored.
- Key forecasting and analysis methods will be matched to appropriate problems.

In 2012, Program 178 will consist of two project sets:

- Project Set 178-A continues its focus on conventional and advanced technology cost and performance for new generation capacity screening, with supporting information on technology risks, life-cycle management, regulatory impacts of emissions and portfolio standards, and cost escalation analysis featuring the Technical Assessment Guide (TAG®), generation capacity additions topics, and advanced technology topics.
- A new Project Set 178-B “Power & Fuel Markets: Risk and Response” is being formed by merging two previous and highly complementary project sets on market analysis and market-value/risk methodologies. In addition to ongoing activities, a high priority is research on how to make major generation asset decisions in the face of potentially disruptive uncertainties (e.g., regulations, technologies, and markets) with long-term consequences.
The first project set addresses the power technology theme; the second addresses market analysis and value/risk methodologies. Substantial synergies exist between the two; for example, generation asset planning draws heavily on technology characterizations, but also requires fuel market information as an important input and sensitivity in integrated resource planning (IRP) assessments. Likewise, corporate performance under various technology strategies often is best examined using sophisticated simulations of power markets, revenue-cost spreads, and risks. This program develops information, methods, and case studies across this spectrum to support industry generation and environmental planning and risk management.

**Estimated 2012 Program Funding**

$2.0M

**Program Manager**

Revis James, 202-293-6348, rejames@epri.com
Summary of Projects

178A Technology-Based Business Planning Information and Services (TAG) (069229)

Project Set Description

The electric industry faces declining demand for power, increasing environmental regulations, and an aging infrastructure. However, these challenges are part of a typical industry cycle, and an upward swing in power demand is anticipated in the next few years, which will require new generation facilities to make up for retirements and to meet new demand. The current planning process for new generation facilities requires credible technology information and data that can be customized to individual company needs to meet changing regulatory environments. The Electric Power Research Institute’s (EPRI’s) Technical Assessment Guide (TAG®) project set delivers time-critical, technology-based business planning information, tools, and services that help planners, technologists, engineers, marketers, and financiers optimize capital investments in generation, storage, and transmission and distribution infrastructure. Research priorities in 2012 will include:

- Production of the annual “Power Generation and Storage Technology Options” report, capturing the latest industry data on technologies and cost and performance
- A report on generation capacity impact topics, including technology risks, regulatory impacts, life-cycle management, and cost escalation
- Complementary research completed via supplemental projects, addressing customization of technology evaluation via the TAGWEB™ software, and systemwide planning via the Electric Generation Expansion Analysis System (EGEAS) software.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>P178.001</td>
<td>Technical Assessment Guide (TAG®)</td>
<td>The TAG® focuses on power industry and fuel market developments and asset management questions, drawing on previous studies, premiere analysts, databases, and market simulation techniques to provide critical planning information. In addition to the TAG technical report, project participants can obtain a one-year subscription, from 1/1/11 to 12/31/11 or from 1/1/2012 to 12/31/2012, depending on the project participant funding year for up to five users of the TAG®-Web software package. A development effort is being initiated in 2011 to enhance analytical capabilities and user-friendliness of the Electric Generation Expansion Analysis System (EGEAS) software. It is a web-based integrated resource planning tool that would be seamlessly linked to the TAGWEB™ software for sharing the technology screening results. The funding solicitation for this effort will be initiated on June 1, 2011, with software delivery scheduled for fourth quarter 2012. The supplemental project notice (SPN) for each of these software packages provides additional details.</td>
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</table>

P178.001 Technical Assessment Guide (TAG®) (065783)

Key Research Question

It is anticipated that the demand for power in the United States will pick up in the next few years, and the costs for building new power generation facilities will increase. As the planning process for new capacity additions is fairly long and a diversified set of technologies has to be considered, energy companies need credible and consistent information on the performance and cost of both conventional and emerging power system technologies. Implementation of environmentally friendly and effective, capital-intensive, and long-asset-life technologies is more important than ever before. Developing and implementing strategic technology solutions
require linking technology plans to business plans, which in turn requires critical information on the technologies. This information includes consistent, up-to-date data on the performance and cost of conventional and emerging electricity technologies and facilitates analysis of plant retirements, major asset replacement/refurbishment, and new capacity additions.

**Approach**

The program offers a range of tools — from cost and performance (including emissions) reports to customizable software and technology-planning case studies — that target specific, current issues while staying focused on technology trends. Research covers issues such as cost escalation and credit squeeze for new plants, in addition to the annual cost and performance update for as many as 19 power generation and storage technologies. Examples include understanding and clarifying escalation or decline in project costs; the impact of significant amounts of renewable technologies in the system on baseload technologies; the impact of new EPA emission rules on existing fossil assets; and the role of combustion turbines/combined-cycle systems in planning for new capacity in the near term.

**Impact**

Benefits of collaborative research in this area include:

- Up-to-date market and technology-relevant databases, methods, and tools.
- Quick response to members on current issues.
- Cost and performance data and evaluation tools help participants make decisions on technology choices and facilitate integrated resource planning and interaction with regulatory agencies.
- TAG® is an authoritative source of cost and performance information on advanced and conventional generation, storage, transmission and distribution, and environmental control technologies. The TAG® program format and content are updated annually to meet changing industry conditions.
- Technology planning case studies provide information “upstream” of technology information.
- Project participation includes membership in the Electric Utility Planning User Group (EUPUG), which serves as a forum for planning managers and directors to share ideas and concepts in a peer group.

**How to Apply Results**

Project technical reports help participants with preliminary technology screening, preliminary project planning, negotiating with vendors, and communicating options for new generation capacity to upper management and to regulatory agencies, where applicable. EPRI's program staff performs industry issue-specific analyses to enhance the application of results. The web-based programs provide consistent cost and performance information and methodologies that allow users to customize information to company-specific situations in advanced and conventional generation, storage, and environmental control technologies.

**2012 Products**

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td>Technical Assessment Guide (TAG®): The TAG® contains technology descriptions, trends, design basis, cost estimate bases, and key technology data, including capital costs, operating and maintenance costs, heat rate, and availability. The technology descriptions include an overview of process conditions, emissions and any required controls for effluents, market data including vendor offerings, resource (fuel) requirements and data, current R&amp;D activity, and future potential for enhancements.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Product Title &amp; Description</td>
<td>Planned Completion Date</td>
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<tr>
<td><strong>Generation Capacity Addition Topics - Technology Risks, Life-Cycle Management, Regulatory Impacts, Material, Equipment, and Labor Cost Escalation:</strong> In addition to the cost and performance information on power generation technologies in the Technical Assessment Guide (TAG®), the new generation capacity additions warrant explicit information on complex topics that may affect the capital investment and operating life. In the past, these topics have been addressed to a lesser degree in the TAG® report. In the current environment, the scope of these topics has expanded. This special report would complement the TAG® and would address the implications of technology risks, life-cycle management considerations, regulatory impacts due to emission control requirements, portfolio standards, and cost-escalation impacts on materials (concrete, structural steel, and piping).</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Technical Assessment Guide (TAG®) - Advanced Technologies:</strong> The power generation industry is attracting new capital investments in R&amp;D for the development and implementation of new technologies for new generation and storage capacity additions. Many of the developments are taking place outside the current industry infrastructure and are driven by environmental regulations and expectation of high return on investments. Some of the advanced concepts include integration of currently available commercial technologies such as wind and storage, and solar and storage. A breakthrough in technologies that have been in long development cycles such as fuel cells also is possible. This report would cover the potential for various technologies and provide a feasibility analysis by looking at the various components of the technology and their break-through time frame. In general, the time frame for this would be 2015-2030.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>TAGWEB Software (Supplemental / SDF):</strong> The TAGWEB™ (Technical Assessment Guide Web) software is an integrated, web-based software that provides current cost and performance data and technology trends for:</td>
<td>12/31/12</td>
<td>Software</td>
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<tr>
<td>- Fossil technologies: pulverized coal, coal gasification/combined cycle, fluidized-bed combustion and combustion turbine/combined cycle</td>
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<td>- Nuclear technologies</td>
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<td>- Renewable energy in the form of wind, solar thermal, photovoltaic, geothermal, and biomass technologies</td>
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<tr>
<td>- Small-scale generation such as fuel cells, internal combustion engines (diesel), small CTs less than 25 MW, and microturbines</td>
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<tr>
<td>- Storage technologies represented by compressed air energy, batteries, pumped hydro, flywheels, and superconducting magnetic energy technologies</td>
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<tr>
<td>The TAGWEB™ data facilitates input to simulation models for integrated resource plans, which lead to selection of least-cost technology and fuel choice for the benefit of the public. Ratepayers can benefit from more-informed decisions by utilities and by their PUCs with regard to increased capacity planning and implementation. The Technical Assessment Guide (TAG®) provides data used for analysis by EPRI's Energy Technology Assessment Center, which develops public-domain technical analyses and assessments of energy technologies, energy-economic analyses, and potential for emissions reductions, including CO₂.</td>
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</table>
Electric Generation Expansion Analysis System - (EGEAS) Software (Supplemental / SDF) Version 10.0: EGEAS (Electric Generation Expansion Analysis System) is a state-of-the-art modular production costing and generation expansion software package, developed under EPRI sponsorship, for use by utility planners to develop and to evaluate integrated resource plans, avoided costs, and plant life management plans. It also has modules that accommodate demand-side management options and facilitate development of environmental compliance plans. EGEAS contains three capacity analysis options that range from preliminary analysis tools based on screening curves to sophisticated non-linear optimization using generalized Benders decomposition and dynamic programming algorithms. A stand-alone, detailed probabilistic production-costing algorithm also is available for production cost and reliability analyses.

- The key features of EGEAS are:
  - Dynamic programming logic to form candidate portfolios from identified alternatives, meeting a capacity planning constraint (e.g., maintain x% reserve margin).
  - Conducts Present Value Revenue Requirement or lowest-electric-rate economic ranking of candidate portfolios dispatched with an existing and future set of assets.
  - Ability to quickly run a number of scenarios to test different generation plans.
  - Simple economics — easy to understand and explain results.
  - Well-accepted by regulators.

Current applications:
- Front-end screening tool.
- Asset retirement evaluations
- Emission evaluations from power plants

EGEAS has particular capabilities that are highly valued by utilities. It can be used to determine a reduced number of portfolios requiring a more detailed analysis (hourly dispatch, stochastic analysis) of fuel and transmission-related costs. It also provides the option to limit run time for specific portfolios.

PS178B Power & Fuel Markets: Risk and Response (072104)

Project Set Description

This project set integrates the research formerly carried out in separate projects sets on market analysis and value/risk/planning methodologies. The research is now organized into three projects having complementary analysis and methodological components as outlined below. Specific scope will be updated to reflect member priorities in response to ongoing research findings and critical issues.

The areas of focus of the projects are:
- Market developments in fuel and power pricing, with implications for market forecasting and modeling. Examples include continuing shifts in generation (e.g., coal displacement by natural gas), shifts in peak and off-peak price spreads, and gas/power price volatility.
- Information and methods for optimizing value and risk of an energy portfolio, with focus on market forces and operational uncertainties. In addition to enhancing the range of EPRI’s Energy Book System, examples include the use of heat rates as a commodity of trade and forecasting and managing increasing instability of coal burn.
• Making major portfolio decisions that have long-term consequences, given the likelihood of highly disruptive changes in regulations, technology, market, and consumer demand. Examples include how regional fleet transition, uncertain in timing and extent, affects portfolio performance; and drawing lessons from international asset shifts.

<table>
<thead>
<tr>
<th>Project Number</th>
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<tr>
<td>P178.002</td>
<td>Power &amp; Fuels: Industry Development and Market Evolution</td>
<td>The power industry is facing an unprecedented magnitude of uncertainty in technologies, regulations, fuel/power market behaviors, and consumer demand. Decision making, whether it be transactions for near-term risk mitigation or major commitments on the longterm asset mix, requires up-to-date information on fuel market behaviors and implications for asset utilization. This project will assess energy market developments to provide in-depth understanding of the changing generation infrastructure; related markets in coal, natural gas (NG), and emission allowances; and impacts on generation assets. Moreover, this project will assess implications for methodologies of forecasting and modeling market behavior, which are essential inputs to decisions regarding asset mix and financial risk management.</td>
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</table>
| P178.003       | Energy Markets & Assets: Optimizing Value and Risk                            | The energy business is prone to substantial and complex financial risk. This project continues EPRI’s research on algorithms and methods to help members assess and hedge portfolio risk exposures to key industry uncertainties and will now reflect updated assessments on the nature of these risks as well. These uncertainties include:  
• Price volatility and correlations of fuel, power, transmission, and emissions markets;  
• Counterparty credit uncertainty and collateral estimation;  
• Intermittent generation (wind, solar) impacts on supply and operational uncertainties;  
• Regulatory uncertainty, such as carbon restrictions or renewable requirements  
• Load uncertainty, including disruptive developments such as energy efficiency, large-scale price-demand response, and plug-in hybrid vehicles |
| P178.004       | Portfolio Migration: Asset Deployment in an Era of Disruptive Uncertainty     | This project provides information and methods to assist in assessing long-term implications of generation asset-planning strategies in the face of substantial long-term uncertainty. Initial focus is on coal generation retire/retrofit decisions, because these are in the forefront of utility planning today, pushed by local regulations and EPA regulations (e.g., SO₂/NOₓ under the Transport Rule, mercury/other toxics under HAPS MACT, water intake structure parameters, and ash disposal requirements). |

### P178.002 Power & Fuels: Industry Development and Market Evolution (072101)

#### Key Research Question
This project examines the interface between the power industry and its use of fuels. Coal and gas markets will be shaped by events in the power sector. Fleetwide SO₂ controls, for example, will alter coal selection and coal flows. Both coal and gas markets will be affected by large-scale retirements throughout the decade. Following on the program's 2011 analysis of coal markets, the prominent issue slated for 2012 is instability in the gas market — currently in oversupply at unsustainably low prices but facing a potential surge in demand.
The tensions of this dynamic combine the leading economic and environmental forces of the day and are central to generation planning and risk assessment. Moreover, natural gas prices and gas-linked power prices are moving into a new regime created by gas shales, calling for new characterizations of volatility and correlation. Significant shifts in coal selection are also triggered, and these dynamics are occurring at a global scale. EPRI is well-positioned to bring new insights into these assessments due to its position in the sector incurring the greatest changes in fuel use.

**Approach**

This project will assess energy market developments to provide in-depth understanding of the changing generation infrastructure; related markets in coal, natural gas (NG), and emission allowances; and impacts on generation assets. Moreover, this project will assess implications for methodologies of forecasting and modeling market behavior, which are essential inputs to decisions regarding asset mix and financial risk management.

Delivery will be via reports, webinars, advisory presentations, newsletters, and the following major annual seminar held late in the year:

- **EPRI-EEI Annual Seminar on Power Technology, Fuel Supply and Market Risk.** This flagship event delivers and expands upon EPRI’s research findings and introduces topics of growing urgency for consideration by planners and as topics for future research.
- **Newsletters.** The project issues a series of newsletters (articles) on new power plants, retirements, research findings, and timely research topics not addressed in the primary deliverables.

Scope and focus of research, subject to changes per member input as markets evolve, will be as follows:

- **Generation Shifts.** Gas oversupply, recession, and renewables have greatly affected power generation since late 2008. Vulnerabilities of segments of coal generation have been magnified, and natural gas use has gained greatly. EPRI will apply its experience in monitoring and interpreting these forces.
- **Gas Supply and Pricing Scenarios/Adjustments to Oversupply.** Gas market evolution in the United States has both national and global importance. Production has become decoupled from price, raising questions about the timing of adjustments and eventual equilibrium prices. At the same time, the industry is retiring greater amounts of coal-fired generation, with implications for escalating demand. Analysis will examine the fundamentals and knowledge gaps behind price scenario development.
- **Energy Market Modeling.** A key question in energy market modeling is how peak and off-peak power price spreads and their volatilities may change with continuing shifts in the generation mix, penetration of renewables, and expansion of efficiency programs. Another key question is how the diversification of gas supply sources with gas shale development is changing natural gas pricing volatility and correlations, entering a regime that departs from historical relationships. EPRI will assess these changes, which will become inputs to power and natural gas transactions-centered work in the next project.
- **International Markets topics: Coal Trade and LNG Pricing.** The United States has shifted from being a potential top-tier LNG importer, which triggered vast investments in liquefaction and regasification, to being an exporter of price depression. Oil-linked pricing is under pressure both in Europe and Asia, countered to some extent by a step-up in Japan’s LNG reliance. The international coal trade has reached new heights, with no impetus at all from shipping rate escalation that accompanied the 2008 run-up. Its development and adjustment will impact U.S. domestic coal prices and possibly call for rethinking coal equilibrium pricing. Sound analysis and case studies will help planners gauge these developments.

In addition to the studies outlined above, this project is closely linked to one of the proposed supplemental studies, “Displacement of Coal Generation by Natural Gas: Limits and Implications of Alternative Dispatch of Fossil Units”. Touted as a low-cost measure to reduce CO2 emissions, a detailed and comprehensive understanding of dispatch economics and transmission is needed to quantify the impacts of coal displacement policies including gas demand levels.
Impact

Fuel is an enormous expense for energy firms, and relative pricing among fuels dictates generation asset utilization. Moreover, fuel prices are volatile in the short run and exhibit very large swings over time. Improvements in understanding the trends in fuel pricing and linkages to power pricing will enhance decision-making and provide extremely valuable leverage to the enterprise.

How to Apply Results

Information delivered via reports, webcasts, seminars, and newsletters will improve staff decision-making. There are opportunities for custom or collaborative projects to help ensure effective application of knowledge and extend the research yet further.

2012 Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>EPRI-EEI Annual Seminar on Power Technology, Fuel Supply and Market Risk, and Series of Newsletters: This flagship annual event draws together practitioners and researchers to address the principal issues affecting energy planning and market development, with implications for planners, risk managers, traders, and forecasters. A primary focus of this event and the series of newsletters is presentation and elaboration upon EPRI's recent research findings, introducing topics of growing urgency as well as future research.</td>
<td>12/31/12</td>
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<tr>
<td>Gas Supply, Generation Shifts and Pricing Scenarios: Gas market evolution of recent years has both national and global importance. Gas oversupply, recession, and renewables have greatly affected power generation since late 2008. Vulnerabilities of segments of coal generation have been magnified, and natural gas use has gained greatly. In some cases, production has become decoupled from price, raising questions of the timing of adjustments and eventual equilibrium prices. At the same time, the industry is retiring greater amounts of coal-fired generation, with implications for escalating gas demand. Analysis will examine the fundamentals and knowledge gaps behind price and supply scenario development. This information is essential to evaluating risks associated with different retire/retrofit/replace strategies.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Energy Market Modeling: Regime Change under Shales, Coal Retirements, and Shifting Demands: Energy planners and financial risk managers need models that reflect current and anticipated price behaviors. Major changes in fuel supply, power demand, and regulations are causing unprecedented and little understood changes in market behaviors. Two principal thrusts of this line of research proposed for this year include: a) potential changes in peak/off-peak power price spreads and their volatilities, as there are shifts in generation mix, and b) natural gas pricing volatility and correlations, entering a regime altered by gas shale supplies. These issues affect both transactions and technology choice (e.g., value of storage).</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>International Markets: Coal Trade and LNG Pricing: This report presents top issues in international generation and fuel markets, both influencing and influenced by U.S. power sector evolution and fuel markets. Global forces continue to affect local coal prices, for example, and the United States is currently exporting price depression in natural gas prices. This analysis will also help frame longer term equilibrium levels in both traded coal and LNG. The latter is particularly important to the period of reintegration of U.S. and global gas markets. These developments affect longer term performance of assets.</td>
<td>12/31/12</td>
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P178.003 Energy Markets & Assets: Optimizing Value and Risk (072102)

**Key Research Question**

The energy business is prone to substantial and complex financial risk. This project continues EPRI’s research on algorithms and methods to help members assess and hedge portfolio risk exposures to key industry uncertainties and will now reflect updated assessments on the nature of these risks as well, such as:

- Price volatility and correlations of fuel, power, transmission, and emissions markets;
- Counterparty credit uncertainty and collateral estimation;
- Intermittent generation (wind, solar) impacts on supply and operational uncertainties;
- Regulatory uncertainty, such as carbon restrictions or renewable requirements;
- Load uncertainty, including disruptive developments such as energy efficiency, large-scale price-demand response, and plug-in hybrid vehicles.

The emphasis of this project is on how to best respond to the many changing and uncertain fundamentals affecting portfolio opportunities and risk. Thus, the emphasis is on transactions, spanning sales and purchases of power, fuel, capacity, and emissions allowances. The research draws on mature capabilities developed in the pre-existing research programs combined here, including the Energy Book System (EBS) software.

**Approach**

This project performs a mix of market studies, custom case studies, and algorithm development. Delivery will be via reports, webcasts, advisory presentations, application of program software, and updated software:

- **Energy Book System (EBS).** EPRI’s Energy Book System has continued to develop capabilities through base and supplemental research. Developed as a research tool for market-based value and risk analysis of energy assets and portfolios, it has proven useful to many power companies for risk analysis and asset planning. EBS can be used in custom projects and often serves as the testbed for new algorithm development.

Additional topics of focus for 2012 are as follows, subject to changes per member input:

- **Estimation and Use of Implied Heat Rates in Transaction Planning.** Heat rates have become a widely used marker in energy (power) trading and market forecasting. An advantage is that they project the balance of required production units and loads upon which to layer-in natural gas price volatility. This research will examine the practices of projecting heat rates, their comparative volatility, and their use alongside price measures in regions with different generation mixes.

- **Survey of Regulation and Practices Regarding Hedging.** Hedges, such as forward contracts for power or fuel, reduce future cash flow uncertainty but at the risk of locking prices that may appear unfavorable with hindsight. Furthermore, application of even the most carefully considered opinions on hedging decisions may be seen by regulators as speculation entailing unfavorable rulings in rate cases. This research will examine actual hedging practices and contrast with views and rulings by regulators.

- **Fuel and Transportation Procurement.** Uncertainty of fuel burn is growing in parts of the country subject to the greatest swings in relative fuel prices or wind penetration. This work will examine the adaptations in fuel and transportation procurement that are being triggered by greater instability in coal burn and by greater use of natural gas, documenting impacts on both the power and fuel industries.

In addition to the studies outlined above, this project is closely linked to one of the proposed supplemental studies, “How to Optimize Timing and Nature of Forward Generation Commitments.” A common but challenging task for owners of generation, particularly IOUs and unregulated producers, is how much and how far in advance to lock in output quantities and prices. The balancing of risks and opportunities under uncertainty, and clarifying the nature of tradeoffs, requires quantitative modeling.
Impact

Failure to properly assess and manage risk exposures can result in suboptimal or even catastrophic performance. Improvements in assessments of market-based value and financial risk management have very high leverage in terms of cash flow and business stability.

How to Apply Results

Information delivered via reports, webcasts, and software will improve staff decision-making capability. There are opportunities for custom or collaborative projects to help ensure effective application of knowledge and extend the research yet further.

2012 Products

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<tr>
<td><strong>Energy Risk: Methods and Measures under Disruptive Uncertainty:</strong> EPRI</td>
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<td>has been developing and refining influential algorithms for assessment of market-based value and risk in energy portfolios since the beginning of power markets in the mid-1990s. Many such methods have been embedded into EPRI's Energy Book System software, as a test bed as well as operational use. Current attention is focused on potential changes in market modeling (&quot;regime change&quot;) due to gas price volatility and the power-gas price relationship, as well as &quot;course correction&quot; analysis as the future includes potentially highly disruptive uncertainties in regulations and technology. By keeping current, planners will continue to be able to address today's most pressing issues and decisions requiring risk quantification. Algorithms are published in reports. Inclusion in software depends on membership needs.</td>
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<tr>
<td>Implied Heat Rates: Estimation and Use in Risk Analysis and Transaction Planning: Heat rates have become a widely used marker in energy (power) trading and market forecasting. This report will examine the practice and roles of using heat rates as a supplement to more traditional price measures. This research has the potential to offer planners and risk managers additional insight into market behavior, and to bridge experience across energy trading and fundamental assessments.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<td>Hedging and Power/Fuel Procurement: Regulations, Trends and Practices: This report examines practices of hedging power and fuel management with a principal thrust to survey and draw lessons from the treatment of hedges across the regulatory community. Among the topics, there is growing interest in the term of gas supply agreements. Moreover, there is continuing tension between reducing future cash flow uncertainty and locking prices that may become unfavorable with hindsight. A further challenge is increasing instability in coal burn. Benefits include cross fertilization and improved public understanding of risk management value, regardless of market direction.</td>
<td>12/31/12</td>
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P178.004 Portfolio Migration: Asset Deployment in an Era of Disruptive Uncertainty (072103)

Key Research Question

This project provides information and methods to assist in assessing long-term implications of generation asset-planning strategies in the face of substantial long-term uncertainty. For example, potential coal generation retire/retrofit decisions are in the forefront of utility planning today, pushed by local regulations and EPA regulations (e.g., SOx/NOx under the Transport Rule, mercury/other toxics under HAPS MACT, water intake structure parameters, and ash disposal requirements). Timetables and approaches to restricting CO2 emissions may change, but the direction is clear.
This project conducts studies and simulations to complement other research addressing key drivers and trends in transformation of the generation fleet. It builds on the program's first study of a hypothetical fleet and its performance under rapid and deferred retirements. The aim is to provide insights into both: 1) the scale and nature of market/revenue impacts, and 2) methods of assessing increasingly dramatic changes in the generation mix. After integrating knowledge gained in the accompanying supplemental research, this work will provide guidance on retirement planning that links capacity and operational components.

Approach

Power companies have to make major asset decisions now, with long-term consequences, yet the future holds potentially major disruptions in regulations, technology, markets, and consumer behavior. This project selects one or more timely topics in major asset decision-making and provides research via analysis, surveys, and algorithm development.

- **Case Studies of Portfolio Migration.** Several topics for case studies are currently proposed here, whose precise definition will be modified on completion of ongoing related research and committee priorities. One topic, "Impact of Regional Fleet Transition Uncertainty on Company Portfolio Planning," addresses large but uncertain changes in the pace of retirements/replacements at a regional/interconnection level. An undertaking of enormous scope and complexity, the goal is to determine how industry responses are themselves a collective variable and source of risk in individual company planning. A second topic for consideration is quantifying tradeoffs between high capital cost/low fuel cost (nuclear, coal with carbon capture and storage) and low capital cost/(potentially) high fuel cost (natural gas combined cycle) generation options. This topic would be aimed at longer-term planning by which time natural gas price escalation is a more tangible risk.

- **Critical Infrastructure Characterization.** Coincident development of, or access to, electric transmission, renewables, water supplies, and natural gas are critical stages in portfolio development. A first emphasis in this series is characterization of pipeline and gas storage costs to serve power company requirements. Particularly in regions with less well-developed gas delivery infrastructures, the power sector may require substantial capital investments by the natural gas industry to build or expand pipeline capacity and gas storage to provide reliable natural gas supplies. To complement the preceding power sector-focused studies, this assessment will review costs associated with gas delivery, reasons for their variation, and their means of payment. Drawing in part on national-scale studies, this work will translate cost consequences to the smaller scale of individual company commitments and transactions.

- **Lessons from International Generation Shifts.** Recent and near-to-intermediate term changes in generation offer lessons in coal retirements, natural gas capacity additions, renewables penetration, and operational considerations. In addition to updating EPRI's examination of the Spanish experience, this study will examine additional regions undergoing substantive change — e.g., Ireland and the United Kingdom — and identify important planning considerations that should not be overlooked.

In addition to the studies outlined above, this project is closely linked to several proposed supplemental studies:

- "Timelines for Capacity Turnover: Gauging Impacts of Multiple Factors and Stakeholders on the Pace of Retire/Replacement Decisions," an effort to convene and tap regional working groups to incorporate practical insight into how fast things can get done;
- "Accommodating Swing: Frontiers in Resource and Operational Planning for Flexibility," a hard look at impacts of coal retirements on how to provide load-following capabilities; and
- "Adding Course Correction Flexibility to Medium/Long Term Generation Planning," an effort to weigh and contrast generation choices that offer different tradeoffs of capital commitment, fuel cost risks, payback periods, and “off ramps.”
Impact

Given the substantial future uncertainties in technology, markets, regulations, and consumer behavior, there is potential for large investments today to become uneconomic prior to providing sufficient cash flow to cover their cost. Improved analysis and planning can help craft portfolio strategies that minimize this risk.

How to Apply Results

Information delivered via reports, webcasts, and algorithms will improve staff decision-making capability. There are opportunities for custom or collaborative projects to help ensure effective application of knowledge and extend the research yet further. Results will be designed to complement existing member planning efforts and facilitate evaluating the viability of different assetplanning strategies under alternative possible future scenarios.

2012 Products

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<tr>
<td><strong>Generation Fleet Transition: Case Studies of Major Build/Retire/Repower Decisions under Regulatory and Technological Uncertainty:</strong> Power companies have to make major decisions regarding generation projects now, with long-term consequences under regulatory and technological uncertainty. With guidance from utilities having alternative experiences and perspectives, case studies will quantify critical decision factors. Topics are anticipated to include uncertainties derived from the unpredictability of simultaneous responses across regions beyond the scale of typical corporate planning, and traditional tradeoffs between capital and risk.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<tr>
<td><strong>Generation Fleet Transition: Critical Infrastructure Characterization:</strong> The first topic in this line of supporting research on non-generation infrastructure is a characterization of economic considerations in costing the gas supply chain needed to support gas projects, the growing default option for dispatchable new capacity. These insights will help firms understand the costs and risks of their gas supply options, and alternative financing.</td>
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<td>Technical Update</td>
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<tr>
<td><strong>International Generation Shifts: Trends and Implications:</strong> The international experience offers a rich literature in coal retirements, natural gas capacity additions, renewables penetration, and operational considerations. In addition to updating EPRI’s examination of the Spanish experience, this study will examine additional regions undergoing substantive change — e.g., Ireland and the United Kingdom — and identify important planning considerations that should not be overlooked.</td>
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Supplemental Projects

Electric Generation Expansion Analysis System (EGEASWEB) (072152)

Background, Objectives, and New Learnings

EGEAS (Electric Generation Expansion Analysis System) is a state-of-the-art modular production costing and generation expansion software package developed under EPRI sponsorship for use by utility planners to develop and to evaluate integrated resource plans, avoided costs, and plant life management plans. It also has modules that accommodate demand-side management options and facilitate development of environmental compliance plans. EGEAS contains three capacity analysis options that range from preliminary analysis tools based on screening curves to sophisticated nonlinear optimization using generalized Benders decomposition and dynamic programming algorithms. A stand-alone, detailed, probabilistic production-costing algorithm is also available for production cost and reliability analysis.

- The key features of EGEAS are:
  - Dynamic programming logic to form candidate portfolios from identified alternatives meeting a capacity-planning constraint (e.g., maintain x% reserve margin).
  - Conducts Present Value Revenue Requirement or lowest electric rate economic ranking of candidate portfolios dispatched with an existing and future set of assets.
  - Ability to quickly run a number of scenarios to test different generation plans.
  - Simple economics - easy to understand and explain results.
  - Current applications:
    - Front-end screening tool
    - Asset Retirement evaluations
    - Emission Evaluations from power plants

EGEAS has particular capabilities that are highly valued by utilities. It can be used to determine a reduced number of portfolios requiring a more detailed analysis (hourly dispatch, stochastic analysis) of fuel and transmission-related costs. It also provides the option to limit run time for specific portfolios.

Project Approach and Summary

This project will develop an enhanced Version 10 with a substantially improved user interface.

A nonworking prototype has been developed in 2010 as a platform for developing a new version of the EGEAS software capable of operating in the web environment with remote access and will focus on the following activities: 1) development of a new web-based Graphical User Interface (GUI) to enhance the useability and user-friendliness of the EGEAS software, 2) implement new enhancements for variations in data input and results, and 3) implement program structure to keep up with the operating system platform changes in the software industry. EPRI’s staff software programmers proficient in Fortran coding and in the latest GUI development technology will be involved in the new version development.

The proposed EGEAS Software Version 10 development will set up a baseline for the EGEAS software to operate in a web-based environment and to evaluate the impact of new technologies in system planning — e.g. renewable technologies on a large scale as well as on a distributed small scale, incorporation of storage technologies, fuel cells, and plug-in hybrid electric vehicles

Benefits

EGEAS has the following applications:

- Generation expansion plans
- Environmental dispatch and optimization
- Integrated resource planning studies (IRPs)
- Analysis of independent power producers (IPPs)
- Power pooling and economic dispatch studies
- Impacts of cogenerators and small power producers
- Marginal cost, contract, and other rate evaluations
- Plant life management and repowering evaluations
- Avoided energy and capacity costs
- Reserve and system reliability analyses
- Generating unit evaluation with bid-based pricing
- Evaluating demand-side management options
TAGWEB™ (055977)

Background, Objectives, and New Learnings

The TAGWEB™ (Technical Assessment Guide Web) software is an integrated, web-based software that provides current cost and performance data and technology trends for:

- fossil technologies: pulverized coal, coal gasification/combined cycle, fluidized-bed combustion, and combustion turbine/combined cycle
- nuclear technologies
- renewable energy in the form of wind, solar thermal, photovoltaic, geothermal, and biomass technologies
- small-scale generation such as fuel cell, internal combustion engines (diesel), small CTs less than 25 MW, and microturbines
- storage technologies represented by compressed air energy, batteries, pumped hydro, flywheels, and superconducting magnetic energy technologies

The TAGWEB™ data facilitates input to simulation models for integrated resource plans, which lead to selection of least-cost technology and fuel choice for the benefit of the public. Rate payers will benefit from more informed decisions by utilities and by their PUCs with regard to increased capacity planning and implementation. The Technical Assessment Guide (TAG) provides data used for analysis by EPRI’s Energy Technology Assessment Center, which provides public-domain technical analyses and assessments of energy technologies, energy-economic analyses, and potential for emissions reductions, including CO₂.

Project Approach and Summary

Several new capabilities have been added based on 2010 research. Database updates were based on the research in the following areas:

- 2008 fluctuation in the financial markets and its impact on new power plant project execution
- Impact of 2008/2010 recession on prices of bulk materials (piping, structural steel, and electrical cables), labor, and equipment used in power plant construction
- Continuing impact of global warming concerns, particularly CO₂ emissions, on continued operation of existing and planning for new fossil-fuel-based power plants
- New trends in technology designs that enhance performance

In addition to the annual technology cost and performance evaluations, the TAGWEB database has been significantly enhanced to reflect current market conditions and technology trends in the following areas: cost and performance updates for Pulverized Coal, large Combustion Turbine/Combined Cycle, Nuclear, Solar Thermal (ST), Photovoltaic (PV), Biomass, Wind, and Storage technologies.

The following topics have also been addressed and included in the 2010 TAGWEB database: CT/CTCC demand and market impact, transmission impacts due to generation capacity addition/reirement, cycling duty impact on PC and CTCC plants, environmental emissions and control, impact of worldwide construction activity, and analysis of cost escalation impacts on future power plants. The TAGWEB software was also enhanced with modeling capability for evaluation of renewable/storage technologies, analysis of data, and improved user friendliness. The TAGWEB software platform has also been upgraded to the .NET environment to enhance its graphical user interface (GUI), and upgrades to the analytical and reporting functions have been added to evaluate options for current industry uncertainties.

Benefits

An overview of the TAGWEB™ software and its benefits are provided below:

- “One-Stop” information source and analytical tool for capital investment planning
- Consistent, credible, current information
- Extensive research on specific technologies and competing options
- Cost and performance information on advanced and conventional generation, storage, and environmental control technologies
- Analyze key uncertainties, such as:
  - What if natural gas prices increase by 20% in one year, in five years
  - What if combustion turbine heat rates increase by 10% after 2 years in operation
  - What if initial market price for electricity is only 1¢/kWh. How does it affect return on investment (ROI)
  - How do I analyze market uncertainties with respect to technical parameters
  - Which electricity technologies should be considered
  - How do renewable and storage technologies fit into future planning
Timelines for Capacity Turnover: Gauging Impacts of Multiple Factors and Stakeholders on the Pace of Retire/Replacement Decisions (072106)

Background, Objectives, and New Learnings
Accelerated replacement of coal-fired units, first anticipated in response to possible CO₂ regulation, is now being driven by air quality regulation and consent decrees. The market and policy modeling community is being caught short by this phenomenon, because industry-scale assessment tools cannot portray the effects of numerous local considerations that affect capacity retirement and replacement. The objectives of this study are to identify pacing factors and their variation and to offer “rate factors” for capacity turnover in different time blocks. This new dimension of analysis will inform planners’ interpretation of forecasts, anticipation of bottlenecks, estimation of costs and rates, and planning for risks and contingencies.

Project Approach and Summary
This project will integrate knowledge and data from regionally-informed agencies and stakeholders to identify the procedures and quantify the range of factors that will shape how rapidly regulated and unregulated entities in the power industry can retire plants, add new capacity, trigger investments as needed in the fuel supply chain, and maintain reliability throughout this process. A core regional working group will be convened, to be comprised of utilities, architect engineers (A/E), regional reliability organizations, EPRI, and others. The principal objective is to identify the scope and interrelationships of critical steps and to estimate “rate factors” (plus the uncertainty around them), which companies and others can incorporate in investment, market, and policy assessments as they see fit.

Segments to be represented will include generation, engineering and design, procurement, labor management and construction, transmission, gas transportation and storage, regulators, land acquisition, land use management and agency oversight, financial entities, and other stakeholders/influencers. As a first cut, EPRI will coordinate development of a research network that can piggyback on regional reliability organizations and A/E experience, expanding to address the additional issues that must be considered.

Benefits
Although models permit specification of large-scale retirements of capacity in relatively short periods of time (e.g., 33 GW of coal in five years), several challenges would be involved in implementing such a scenario. The many factors involved in plant retirement, retrofitting controls, and installing new capacity are known within individual companies, but the elements are numerous and complex, and some are outside recent experience (e.g., building into a low or declining load environment, and incurring massive changes simultaneously across the industry). This study will bring a new and practical dimension to energy analysis, modeling, and both private and public impact assessments by translating these factors into parameters representing realistic limitations to the capability to turn over capacity.
Displacement of Coal Generation by Natural Gas: Limits and Implications of Alternative Dispatch of Fossil Units (072107)

Background, Objectives, and New Learnings

Coal generation is vulnerable to many forces and policies, and gas supply faces many uncertainties. Into this mix, coal displacement by natural gas — pushed by proactive policies — remains poorly understood in detail, and therefore in aggregate, in spite of being highly amenable to analysis. Respected organizations, such as the Congressional Research Service and MIT in its Future of Natural Gas initiative, have offered indicative findings based on simplifications and assumptions. Extending this earlier research, additional analysis will add the rigor necessary to assess potential impacts with confidence.

By conducting comprehensive simulations, EPRI’s series of analyses will assess power flows and feasibility, operational considerations, increased gas requirements, and the important dimension of economic tradeoffs. Among the complexities, the Mid Atlantic and Northeast regions do not have sufficient head room in gas power plant capacity to meet demand in the medium term — a consideration that requires careful attention to seasonal and daily load variation. Further considerations are ongoing coal plant retirements, their impacts on peak/off-peak prices central to coal and gas plant economic evaluations, and transmission system modifications. The many aspects have to be carefully analyzed, using a detailed regional model. In addition to these quantifications, which are important to gas market risk assessment as well as utility asset planning, this work will also advance understanding of how to assess this topic.

Project Approach and Summary

Coal displacement by natural gas is already happening, to an extent far greater than ever seen before. This project draws on EPRI’s recent detailed analysis of those generation shifts and EPRI’s ongoing generation/technology case studies employing state-of-the art simulation. A staged approach is planned, expanding in geographic scope with growing company participation.

Steps include:

Study design and geographic scoping. This step will align participant priorities and resources, evidence of coal unit vulnerability (e.g., EPRI’s generation shifts analysis), and simulation data and capabilities. Time periods for the analysis will also be selected. Due to the scale of a wave of coal plant retirements in response to EPA regulations, selection of time periods/regulatory stringency is a critical step to defining the population of coal units most likely to be displaced.

Scenarios/rules to achieve coal displacement. Defined in terms of economic forces increasing coal generation costs (e.g., due to CO2 measures) or enhancing natural gas generation competitiveness (e.g., due to very low costs of supply). Alternative mechanisms will also be considered.

Methodological guidance/workshop. EPRI will convene a workshop among top practitioners familiar with utility operations and gas/coal competitiveness, project participants, and other stakeholders. Preliminary simulations will be introduced. Following this up, results will be conveyed to a broader audience via webinar.

Generation/transmission/market simulation. Conducted using mature simulation capabilities. The principal simulation engine anticipated for this project is LCG Consulting’s UPLAN modeling suite. Complementary methods of analysis will be applied, contingent on sufficient project resources.

Benefits

Policy considerations are ever-present in economic, technology, and market forecasting. Coal displacement by “unused” gas, achieved by yet-to-be articulated policies, is seen by many as a low-capital-cost means to reduce CO2 emissions and as a means to boost demand for “unused” gas supplies. Simple in concept, how the idea will work in the power industry cannot be easily generalized due to the industry’s great complexity and diversity.
Benefits include better assessment of levels and risks and increased public awareness of potential trade-offs. These benefits derive from quantifying gas market and other impacts arising from this policy dimension. Depending on perspective, these impacts might be considered risks by some and opportunities by others.
Accommodating Swing: Frontiers in Resource and Operational Planning for Flexibility (072108)

Background, Objectives, and New Learnings
Resource planning requirements have been changing. Environmental response planning (retire/retrofit/replacement) is a rapidly growing element of generation planning, but there is an increasing need to accompany this area with planning to accommodate load-following ("swing") requirements. Whether driven by wind penetration or measures that will advance retirements of coal-fired capacity, this shift requires closely integrating operational considerations and constraints into resource planning.

Load-following requirements are incorporated in the ancillary service requirement by most of the independent system operators (ISO). These services are required in the day-ahead market or during the reliability unit commitment (RUC) and supplemental reserve process. Due to increasingly higher requirements to match renewable portfolio standards (RPS), units with flexible output and fast response are in premium demand. Coal retirements are anticipated to produce a similar impact.

The need for flexible units to provide load following will be a growing factor in generation planning. Through a series of case studies aimed principally at the implications of coal plant retirement, this project will advance understanding of the impact and the practice of integrating operational considerations. It is expected that results will indicate that capacity has very different values, depending on the ability of a portfolio of generating and demand-side assets to operate flexibly. Moreover, flexibility may drive the need to add new, flexible capacity ahead of schedules based on resource adequacy (reserve margins) alone.

Project Approach and Summary
Regional case studies will examine how progressive retirement of coal-fired generation in a mixed-generation system causes changes in operating practices (coal cycling, ramping and turndown strategies) and eventually leads to an emphasis on flexibility in replacement capacity (e.g., gas-fired, load-following generation).

Peak and off-peak electricity price spreads and operational flexibility of assets will be key considerations. The loss of traditional load-following resources and increasing reliance on gas-fired capacity may also change the economics of potential energy storage options. It may also reduce the frequency of the use of scarcity pricing for real-time energy.

Case studies will first test and employ models coupling traditional (hourly) and more granular modeling. Alternative research platforms, problems with joint capacity and operational aspects, and geographic areas will be examined with additional case studies, subject to the level of industry participation and priorities. The research plan will be coordinated with EPRI’s wind integration and storage research, where advances in measurement of portfolio flexibility are taking place.

Benefits
EPRI’s case studies, based on real assets in operating markets, will be crafted to illustrate methods to integrate resource and operational planning and the value of doing so. The studies will also show how operational considerations affect decisions on timing and type of replacement capacity, capacity value, the role played by transmission system configurations in different parts of the planning area, and changes in sources of revenue (e.g., energy and ancillary services) across the generation fleet.
How to Optimize Timing and Nature of Forward Generation Commitments (064256)

Background, Objectives, and New Learnings

In the United States, Canada, and many other countries, there are both forward and spot markets for electric power. Owners of power generation resources (and holders of rights to generation capacity) thus face a fundamental question: How far forward in time—that is, how far in advance of production—should they sell the output of their generators.

Due to the volatility of wholesale energy prices, and the corresponding uncertainty about future forward and spot prices, decisions about when to sell power and when to purchase fuel can have a dramatic impact on the revenues and profits that owners realize. These decisions can also have a major impact on the amount of risk generation owners bear.

Although forward transactions can reduce market risks, they can introduce credit risk—the possibility of loss in the event that a contract counterparty fails to pay or deliver. Forward transactions can also introduce risks due to requirements to post collateral or other credit support.

Forward transactions can influence decisions about the type, quantity, and timing of physical capacity expansion, as well as the costs and risks associated with generation resources in place.

Yet, despite the importance of decisions about the timing of power transactions, there is no generally accepted framework for making them.

The purpose and new learning of this research are to construct a framework and methods for making such timing decisions. The results of this research will also serve as a foundation for future phases of this work regarding optimizing the form of generation sales (e.g., energy, capacity, and ancillary services.).

Project Approach and Summary

This project received seed funding from an early participant to identify the motives and factors that influence decisions about how far forward in time—that is, how far in advance of production and delivery—to commit the output of electric power generation resources. The seed phase concluded that decisions about how far forward to commit are tradeoffs between the benefits of risk reduction, on the one hand, and the costs associated with establishing and maintaining forward contract commitments, on the other hand. The seed phase also concluded that decisions about how far forward to sell power may reflect management perceptions of the market—in particular, perceptions that current forward prices are out of line with their expectations for future spot and forward prices, and thus provide opportunities for profitable trade.

Three lines of investigation are planned as next steps. First, because many of the benefits and costs of forward contracting are intangible and difficult to quantify, EPRI plans to create the means to quantify the associated benefits and costs. Second, forecasting (unobservable) future spot and forward prices and translating those forecasts into present-value equivalents to compare with current (observable) forward prices are largely subjective processes. EPRI plans to investigate new ways to perform these tasks.

Finally, EPRI plans to combine the results of these two lines of investigation into an integrated process for decision making.

The approach to this research will include consultation with participating member companies to understand more about the full costs associated with negotiating, executing, and maintaining power and energy contracts; collection of historical data from power and other energy markets; statistical analysis of energy market data; and mathematical modeling of costs and benefits in relation to time.
Benefits

The intended results of this phase of the research will be a framework and methods for calculating the benefits and costs of forward sales of electric energy in relation to transaction lead time, and methods to determine the tradeoffs. The anticipated public benefit will be improvements in the quality of decision making and the allocation of associated risks, resulting in lower production costs and prices. Project participants will enjoy the additional benefits of early access to framework, methods, and prototype utilization, as well as ensuring that the work addresses their business needs.
Adding Course Correction Flexibility to Medium/Long Term Generation Planning (072109)

Background, Objectives, and New Learnings

The electric power industry today faces an extraordinarily high degree of uncertainty. It is not only uncertainty about wholesale power and fuel prices but potentially disruptive factors such as environmental policy, industry regulation, and technological change. Particularly notable in this regard are SOx/NOx/mercury restrictions; natural gas pricing; carbon regulation and pricing; market penetration of automatic meter reading, smart grid and price-responsive demand; electric vehicles; and prospects for major breakthroughs in energy storage technology.

This means that plans made today for acquiring, retrofitting, or retiring power plants are subject to future uncertainties that may sharply increase or diminish the value of the generation asset and alter the relative value of different types of generation assets. For example, the coal plant that you retrofit now may be rendered “out of the money” under substantial carbon pricing or restrictions; the gas plant that you build to fill in the gaps from wind generation may hold little value if there is a substantial breakthrough in economics of electricity storage, or if there is a sharp rise in price of natural gas due to restrictions on shale extraction.

Therefore, generation asset planners face two major analytical challenges:

- **Scenario/simulation analyses should incorporate automated asset-mix “course corrections”**.
  Traditional simulation and scenario analysis methods presume a relatively static portfolio, or one with relatively predictable changes. Planning studies under highly disruptive uncertainty must be enhanced to reflect major changes in asset utilization and portfolio-mix strategies triggered by future “game-changing” events, such as greenhouse gas (GHG) regulation or breakthroughs in generation/storage technologies. In particular, scenarios and simulations must reflect how events such as a tax on carbon emissions would affect: a) the performance of the power generation, transmission, and storage resources in place, and b) the cost and performance of resources that would be installed in response to those events. Studies must reflect the changes in asset-portfolio behavior and managerial strategies when “game-changing” events take place.

- **Investment decision criteria should be adapted to reflect the disruptive nature of the uncertainties**.
  It is well established in economic theory that the traditional “net present value” rule for investment decisions is deficient when uncertainty about the returns to investment is very high. For example, price probability distributions may require “regime change” capability; the “option value” of waiting (i.e., deferring investment decisions) may become a substantial source of value; the insurance value of an asset that protects against certain contingencies becomes relevant. Therefore, the power industry needs enhanced value and decision rules derived for the market and non-market uncertainties that they face.

The objectives and new learning of this research are therefore twofold: 1) to understand how generation planning methods should be changed to accommodate disruptive uncertainties that can lead to major mid-course corrections in portfolio asset mix and strategy, and 2) to understand how investment decision criterion must be altered to reflect the potentially disruptive uncertainties — both market and nonmarket — that the industry faces.

Project Approach and Summary

The project will include three components. The first component will identify and describe the major non-market risks to be subject to further analysis. Currently these risks are anticipated to include emissions regulations/pricing, smart grid, price-responsive demand, electric vehicles, and storage technology. The second and third components will address simulation/scenario analysis and investment decision criteria, respectively.

In the first component, a “technical team” drawn from funders will work with EPRI to identify and describe the key non-market uncertainties bearing on their long-term planning. In the second component, EPRI will work with
one or more funders to adapt existing scenario/simulation planning tools to incorporate opportunities for mid-course corrections. Existing tools such as EPRI’s Energy Book System may be utilized if appropriate. In the third component, EPRI will work with planners at the funding companies and employ finance theory to develop optimal investment strategy change “triggers” for generation resources.

**Benefits**

The intended benefit of this research is an improved understanding of the methodological changes in generation asset planning and decision-making that is required in a power industry facing an array of potentially disruptive uncertainties. The anticipated public benefit will be more efficient power production as the industry makes better decisions regarding its huge capital allocations. Additional benefits for funders will be early access to research results, greater understanding of options and risks involved in investment decision-making, and ensuring that the research is well suited to their business needs.
Environmental Compliance Strategy Support (072068)

Background, Objectives, and New Learnings

Coal today provides over half of U.S. electricity. However, evolving environmental regulation of sulfur dioxide, nitrogen oxides, and mercury combined with possibility of regional and national climate legislation, possible new regulations on cooling technology, and a reconsideration of ash management regulations creates great uncertainty for existing and potential new coal assets. The impacts of these regulations must be evaluated against the backdrop of changing electricity markets. Electricity markets may be fundamentally changed by possible climate policy, whether market based or technology-forcing, and will almost certainly be impacted by significant additions of renewable generation in some regions. Increased abundance of natural gas may be another game-changer.

As companies consider future investments to comply with evolving environmental regulations, the answers may be clear for some older and relatively small units and they may be equally clear for newer and larger units. However for a large fraction of units that fall in the middle of the age-size distribution, the answers will be unclear and will depend critically on how public policy, regulations, and the actions of near competitors evolve to conditions in regional power markets. The basic question becomes whether the cost of investments to keep the unit running can be justified by the future, uncertain value of its output.

While the engineering and technology assessment necessary to assess the retrofit cost is difficult enough, the owner must also assess the unit’s role in the future power market and how that role changes with climate policy or swings in natural gas prices, how it changes with the introduction of new renewable generation, and how it changes as new environmental policies for air, water and ash management lead to the shutdown or curtailment of competing units.

Tens of billions of dollars of value in existing assets are at stake. Having a clear understanding of both the investment worthiness of their existing fleets and the potential value of new generation is needed to help companies make better decisions, and communicate them to stakeholders.

This project is designed to help utilities quantify the potential value of investments in retrofits or in new generation in this evolving world. It intends to give the generation owner a market-based assessment of how much investment its retrofit candidates can support, measured in dollars per kilowatt, and how robust these investments may be under a wide range of plausible futures.

Collectively, the retrofit-retire decisions for the electric sector reflect a potential impact of 100s of billions of dollars for electric customers and consumers of goods and services. This project may lead to improved decision making to help assure that this investment is well spent. Generic (non-proprietary) and general methodological insights from the individual-company analyses conducted through by this project will be communicated through an EPRI Technical Update.

Project Approach and Summary

Project participants identify for detailed study a set of candidate units, possible retrofit investment options, and a range of energy and environmental policy futures. Through past and ongoing Greenhouse Gas Reduction Options program research, EPRI has developed a broad set of analysis tools that greatly increase EPRI’s capabilities to analyze retrofit-retire decisions in a market context. Regional models of the U.S. and regional electricity markets developed as part of the Prism 2.0 project add to this capability. In this project EPRI will adapt and apply these tools to:

- evaluate how much in total one might be willing to invest in each generating unit for all the environmental controls that potentially may be required,
- examine the robustness of the specific investment options of interest across the scenarios, and
- examine the influence of timing of policies and uncertainties on the value of these investments.
The analysis will provide a detailed, bottom-up simulation of the regional power market that calculates the annual distribution of market prices, CO₂ emissions and the cash flows ascribable to each generating unit in the stack.

**Benefits**

Company generation investment strategies are subject to unprecedented uncertainty with regard to the stringency and timing of new environmental regulations, rapid changes in electricity markets driven by the introduction of intermittent renewable generation and the possibility of a future CO₂ price. Making robust investment decisions in the face of these uncertainties can save companies and the public ratepayers billions of dollars as well as provide sound and resolute outcomes which incorporate environmental drivers which may affect the public. Gaining fundamental insights about these uncertainties and possible compliance paths may also help companies inform legislative and regulatory discussions, leading to more effective and efficient regulations.

This analysis provides two features critical to accurate assessment of the value of retrofit investments.

- Market analyses extending to 2050 (encompassing a full lifecycle for new investment) are needed to fully capture the long-term effects of climate and clean energy policies on the recovery of retrofit investments and the addition and mix of new generation.
- Integrated regional market analysis is critical to quantifying the “survivor value” for units that remain in service (after retrofits) following a wave of retirements. These retirements have a direct impact on power prices and thus cash flows underlying retrofit investment worthiness.

Both of these features are outside the scope of most IRP analysis tools, yet are integral to the EPRI modeling approach. Including these issues is critical to fully capturing the value, and risks, to retrofit investments.
Boiler Life and Availability Improvement Program - Program 63

Program Overview

Program Description
The majority of fossil plants worldwide are more than 30 years old and are experiencing increased demand for operational flexibility while addressing age-related issues for major components. High-energy steam and water piping systems also are among the most important safety issues at fossil plants and must be managed reliably through the aging process. Safety and availability loss due to pressure part failures are two key issues driving R&D on major fossil power plant components, especially in older plants. Boiler tube failures (BTFs) continue to be the leading cause of lost availability (with equipment availability losses due to BTFs averaging approximately 3%) in fossil-fired steam plants worldwide.

The Electric Power Research Institute’s (EPRI’s) Boiler Life and Availability Improvement Program (Program 63) uses international collaboration to develop technology and guidance on safe management of boiler component life to ensure high reliability and reduce O&M costs. Efforts focus on advanced inspection techniques for early and accurate identification of component damage; analytical tools to predict remaining life and risk of in-service failure; and decision-support tools to help balance risk and benefit under a variety of operating scenarios.

Research Value
Power generators need to balance the risks and costs of the largest, most costly equipment in the power plant, and focus on using proven technologies to create solutions. By using the results of the R&D in this program, plant owners and operators can:

- Reduce the costs of lost availability due to boiler tube failures from greater than $10,000/MW/yr to less than $1,000/MW/yr when program results are applied comprehensively;
- Increase the safety of high-energy and high-temperature piping systems; and
- Increase safety through control of flow-accelerated corrosion (FAC) in fossil plants.

Approach
The program portfolio includes guidelines, reports, software code, and tools applicable to all boilers, focused on the goal of optimal availability and performance.

- Research for Boiler Component Inspection and Monitoring (P63.001) develops reliable and cost-effective nondestructive evaluation (NDE) techniques to reduce operation and maintenance (O&M) costs and improve life-management options. NDE developments in other industries also are evaluated for application to fossil plants.
- Tools for Boiler Component Life Management (P63.002) provides a comprehensive approach to creating technical bases for minimizing in-service component damage and for component remaining-life assessment. Both areas are critical for high reliability and maximum equipment life.
- High-Energy Steam and Water Piping Safety and Life Management (P63.003) addresses safety and reliability of high-energy piping systems in fossil power plants. Information is provided on how damage mechanisms affect piping components and on remaining life tools. Tools are developed that allow engineers to more accurately predict the remaining life of piping systems.

Accomplishments
EPRI’s Boiler Life and Availability Improvement program has created and successfully demonstrated a world-recognized program to reduce boiler tube failures by understanding damage mechanisms, their root causes, and corrective options for root causes. Highlights include:
• Development of the most comprehensive suite of guidelines and analysis tools for boiler component life management.
• Leading guidance, training, and analysis tools for flow-accelerated corrosion (FAC) management in fossil plants.
• Leadership in developing and demonstrating NDE technologies for boilers, high-energy piping, and FAC.

Current Year Activities
The program R&D for 2012 will focus on developing life-assessment technologies for piping and header base metal degradation. Specific efforts will include:

• Development of small sample removal and testing procedures to predict remaining life of seamless pressure parts;
• Guidance to address damage from evolving operating modes within current fossil fleet, including fuel switching, cycling, low load, and environmental constraints; and
• Technology and information to support reliable operation of new and advanced fossil boiler designs.

Estimated 2012 Program Funding
$4.5M

Program Manager
Kent Coleman, 704-595-2582, kcoleman@epri.com

Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P63.001</td>
<td>Research for Boiler Component Inspection and Monitoring</td>
<td>This project provides technology, tools, and application support to maximize safety and reliability of boiler components and to determine optimal timing for repair or replacement, and investigates new technologies for NDE.</td>
</tr>
<tr>
<td>P63.002</td>
<td>Tools for Boiler Component Life Management</td>
<td>This project focuses on the technology and tools required to cost-effectively minimize boiler tube failures and addresses life management issues associated with high-cost and high-impact boiler components such as tubes, headers, and drums.</td>
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<tr>
<td>P63.003</td>
<td>High-Energy Steam and Water Piping Safety and Life Management</td>
<td>This project provides information about damage mechanisms, their root causes, and appropriate responses to ensure safe operation of high-energy steam and water piping systems.</td>
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P63.001 Research for Boiler Component Inspection and Monitoring (103518)

Key Research Question
Maximizing safety and reliability of boiler components and determining optimal timing for repair or replacement require accurate and timely detection of service-generated damage. New technologies for NDE might allow faster examination of boiler components at lower cost, resulting in shorter outages. This project provides the technology, tools, and application support via R&D, applications, workshops, and training required.

Approach
To achieve longer intervals between inspections and overhauls of boiler components, it is necessary to detect service-related damage at an early stage. EPRI will develop new NDE techniques for detecting damage sooner
than currently is possible. This detection is intended to identify a multiyear period during which the power producer must take action to avoid significant risk of failure during service. EPRI also will pursue NDE alternatives that are faster, better, or cheaper than traditional techniques. Guidance will be developed to ensure effective use of NDE tools.

EPRI will research the science and application of continuous monitoring technologies that provide the largest amount of information on damage initiation and progression. In conjunction with remaining-life models developed under P63.002 and P63.003, these approaches will support optimal decisions for component repair or replacement with minimal risk of failure during the service life.

**Impact**

- Improved reliability and lower O&M costs via reduced risk of service failures
- Extended intervals between examinations through more sensitive and more accurate NDE applied to boiler components
- Reduced O&M costs via more efficient NDE techniques for damage detection
- Demonstration of NDE personnel and technology proficiency, providing companies with more accurate examination results

**How to Apply Results**

Research results to develop new or improved NDE techniques generally will be licensed to commercial NDE companies that will offer the technology for sale or performed as a service. Larger companies might use the results directly via in-house NDE organizations. Guideline reports to support correct application of NDE technology can be used by members as training guides and for process or procedure improvements with an eye to improving reliability while lowering O&M costs. Technology will be presented to members via workshops conducted regionally, in association with EPRI programs or interest group meetings.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Digital Radiography for Other Components:</td>
<td>12/31/12</td>
<td>Hardware</td>
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<tr>
<td>This project will build on the successes obtained using real-time digital radiography to examine boiler tubes. Using similar equipment, the project will evaluate the capability of digital radiography for various components and damage mechanisms.</td>
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| Development of NDE Techniques for Graphitization:  | 12/31/12                | Technical Update |
| Graphitization is a damage mechanism that affects carbon and carbon-molybdenum steels operating at high temperature. Historical damage has been located close to welds in the heat-affected zone (HAZ). Recent failures indicate that bends also are susceptible to this damage mechanism. Traditional inspection involves replication techniques, which are very slow, costly, and only capable of looking at the surface of the material. This project will investigate NDE techniques that can rapidly examine large areas through the complete thickness of common size boiler tubing. |

| Drum Damage Detection and Sizing Guideline:        | 12/31/12                | Technical Update |
| Drums in fossil power plants have experienced damage typical of corrosion fatigue and thermal fatigue. These cracking mechanisms commonly result in a pattern of multiple cracks in proximity to one another. This proximity hinders conventional NDE techniques in accurate sizing of the damage. A guideline document will be prepared that addresses NDE for detection and sizing damage in drums including best techniques and inspection practices. |
**NDE for Attemperator Sprays:** Conversion to Powder River Basin coals have required the duty cycle of attemperators to increase, resulting in damage to nozzles and liner plates. Conventional inspection techniques involve cutting out nozzles and performing visual inspections. NDE techniques will be investigated to understand if inspections can be performed without the need for removing and repairing components.

**Flexible Eddy Current Array Probes:** Progress has been made with the use of printed circuit board (PCB) technology for flexible eddy current array probes. A flexible probe would allow for easier coupling to a robotic device and facilitate remote examinations of components that are conventionally deemed inaccessible. One concept is to incorporate the PCB probe in a glove or similar device such that the probe essentially becomes part of the NDE technician’s finger. The finger could be moved along a surface (which may have changing geometry) and allow examination of rough or changing surfaces. A later step would include the array probe in a robotic system.

**P63.002 Tools for Boiler Component Life Management (103519)**

**Key Research Question**

Boiler tube failures (BTFs) consistently are the leading cause of lost availability for fossil power plants, with equipment availability losses due to BTFs averaging around 3% worldwide. Headers and boiler internal piping continue to age and degrade. This project will continue to focus on the technology and tools required to cost-effectively minimize boiler tube failures. The project also will address life management issues associated with high-cost and high-impact boiler components such as tubes, headers, and drums. The project includes support for implementing a boiler tube failure reduction (BTFR) program, performing life management of headers and drums, and facilitating peer-to-peer communications on boiler issues through the Boiler Reliability Interest Group (BRIG).

**Approach**

Projects will advance the understanding of boiler tube and other pressure component damage mechanisms and their root causes, while establishing programs and corrective actions to control risks of in-service failures. This science and information will be captured in practical guides for fossil plant personnel. As needed, tools for more accurate remaining-life analysis will be created to support the life-management objectives.

**Impact**

- Improve boiler availability through fewer boiler tube failures
- Lower O&M costs through longer operating lives for major boiler components
- Reduce risk of in-service failures in tubes, headers, and drums

**How to Apply Results**

Guidance on boiler tubing, headers, and drums can be used by members to establish a BTFR program and perform life-management analyses. Peer-to-peer communications on boiler issues — optimally, through attendance at the Boiler Reliability Interest Group (BRIG) meetings — allow members to take advantage of industry lessons learned. Analytical tools may be licensed to commercial vendors to market the technology, allowing members to apply the tools directly or via a service. Targeted workshops with EPRI staff bring worldwide expertise to members, increasing the benefit of implementing these research results.
<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Unit Cycling-Influenced Boiler Damage Mechanisms &amp; Predictive Models:</strong> Theory &amp; Practice: This project will provide an overview of each boiler component/damage mechanism that has been identified as being important with regard to unit cycling availability losses or costs in the State-of-Knowledge of the Impact of Unit Cycling on Boiler Component Damage report completed in 2011. For each mechanism, the project will identify the characteristics of the damage and how it is affected by unit cycling. It will also provide guidance on how to inspect for its root cause, determine corrective action, and monitor and predict its unit-cycling-influenced rate of damage. It will do this using simplified, self-calibrating models similar to a corrected version of the probabilistic version of EPRI’s waterwall corrosion fatigue influence diagram model, or to the simple maintenance interval predictive models in the unit-operation-dependent maintenance interval and capital expenditure forecasts used by the steam and gas turbine original equipment manufacturers (OEMs).</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Corrosion Fatigue in Waterwall Tubing in Assisted Circulation Boilers:</strong> EPRI completed a major research project in 2010 that instrumented a natural-circulation boiler with strain gages, thermocouples, and linear variable differential transformers (LVDTs) to determine corrosion fatigue potential during startup and operation. Operational changes were suggested to minimize the damage to waterwall tubing. A parallel effort will investigate an assisted (controlled) circulation boiler. Variables to be investigated include proper time to start boiler circulation pumps on cold, warm, and hot starts to minimize damage, as well as scenarios to control thermal transients during different length outages.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Corrosion Fatigue in Riser and Supply Tubing in Assisted Circulation Boilers:</strong> Corrosion fatigue damage in riser and supply tubing in natural-circulation boilers poses a safety concern. Tubes suffering from this damage mechanism often are outside the boiler setting, in people spaces, where injury risks may be elevated. Although natural-circulation boilers seem to be more susceptible than controlled-circulation boilers, failures have occurred in both. This project will investigate the variables that can be adjusted to minimize damage in riser and supply tubing in controlled-circulation boilers.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<td><strong>Development of Life Calculators for Grade 11 and Grade 22 Materials:</strong> Through the Creep Strength Ferritics Life-Management Program, EPRI developed a simple-to-use life calculator for Grade 91 material. This calculator allows users to input different operational scenarios and calculate when failures would occur. It allows users to select from many different material types, including parent metal, weld metal, heat affected zone, and degraded materials. This project will develop parallel calculators for Grade 11 and 22 to provide a quick, and accurate tool for predicting damage in pressure-containing components.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>In-situ Monitoring to Determine the Effect of Startup Ramp Rates on Superheater/Reheater (SH/RH) Pressure Part Damage:</strong> Startup ramp rates may have a large effect on the life of superheater and reheater pressure parts. Excessive rates may lead to high thermal expansion stress, especially when different materials or thick sections (headers) are involved. It has been established that high firing rates before proper cooling flow may overheat tubing. Rates of oxidation exfoliation also may be accelerated. This project will instrument SH/RH sections in an operating boiler and, through a series of operational transients and startup rates, determine optimal/most aggressive ramp rates allowed.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>
P63.003 High-Energy Steam and Water Piping Safety and Life Management (060364)

Key Research Question
High-energy steam and water piping failures are one of the most important safety and availability issues in fossil power plants. EPRI research has identified key damage mechanisms such as creep, fatigue, and corrosion that can lead to piping failure. Flow-accelerated corrosion (FAC) is a major safety issue in fossil plants. Research continues to refine the understanding of these damage mechanisms and how they are affected by component aging and variation in operating modes for the plant. Safe and reliable operation of piping systems requires active damage prevention, periodic inspection, remaining-life assessment, and repair or replacement programs. These activities require a proactive life-management approach. This project will provide information about damage mechanisms, their root causes, and appropriate responses to ensure safe operation of these piping systems.

Approach
Projects will improve the understanding of damage mechanisms and their root causes, and will establish programs and corrective actions to control risks of in-service failures. Tools for more accurate and cost-effective analysis of damage rates will be created. This project will begin to develop life-assessment tools to address aging of base metal in traditional and advanced ferritic piping systems.

Impact
- Reduce risk of high-consequence failures of high-energy steam and water piping systems by applying tools and guidance developed by this project
- Eliminate FAC as a safety issue in fossil plants
- Reduce O&M costs associated with piping life management by improving inspection accuracy and efficiency
- Reduce O&M costs by lessening very conservative assumptions of piping life and providing more accurate assessment of timing for pipe replacement

How to Apply Results
This program will help members establish a proactive life-management approach to high-energy piping systems and FAC control. This project will provide information about damage mechanisms, their root causes, and appropriate responses to ensure safe operation of these piping systems, and will include workshops and training to ensure proper application of life management processes. Advanced analysis tools developed in the project may also be licensed to third parties for application to fossil plants.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Updates to EPRI Fossil FAC Advisor</td>
<td></td>
<td>Software</td>
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<tr>
<td>Fossil FAC Advisor Workshop</td>
<td></td>
<td>Workshop, Training, or Conference</td>
</tr>
<tr>
<td>Piping Parent Metal Life Assessment</td>
<td></td>
<td>Technical Update</td>
</tr>
<tr>
<td>Product Title &amp; Description</td>
<td>Planned Completion Date</td>
<td>Product Type</td>
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<tr>
<td><strong>Best Practices for Thermowell and RT Plugs</strong>: Thermowell and radiography plug design and installation always are a concern in high-energy piping. This R&amp;D will investigate the best practices in design, fabrication, installation, and testing to provide optimum life of these components.</td>
<td></td>
<td>Technical Update</td>
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</tbody>
</table>
Supplemental Projects


Background, Objectives, and New Learnings

Detection of wall thickness degradation caused by FAC in power plant piping and components is of primary concern to utilities because of the extensive damage to plant equipment and potential for loss of life that can result from this damage mechanism. Because the large amount of piping that FAC can affect typically are insulated, conventional nondestructive evaluation (NDE) for FAC has been very costly and time-consuming.

Project Approach and Summary

This project will expand on EPRI’s 2008 evaluation of complementary metal oxide semiconductor (CMOS) technology as a direct digital radiographic detector for identification of corrosion fatigue cracking in boiler waterwall tubing. That project determined that a CMOS detector is fully capable of detecting corrosion-fatigue cracking in boiler waterwall tubes while in place, and through insulation and other building structure around the boiler.

This expansion of that work will quantify the capability to detect wall thinning and will develop a mechanism whereby the CMOS detector can be manipulated along the length and around the circumference of piping systems. Proving this capability would represent advancement on the state-of-the-art of this emerging technology, moving it closer toward commercial application.

Benefits

The ability to detect FAC with a digital radiographic system without removing the insulation could be of very high value to operating plants, which currently have limited means of detecting such damage. Current NDE consists of either removing insulation to obtain detailed ultrasonic thickness measurements on a tight grid pattern throughout the length of susceptible piping, or obtaining an average thickness over a large area with pulsed eddy current technology through the insulation. Early detection of damage prior to failure will help to keep the operating plants safe and will reduce costs due to failure, including loss of equipment or injury to plant staff. This less-expensive screening method for FAC would result in safer power plants, reducing the cost of electricity generation.

Background, Objectives, and New Learnings
As power plants continue to age, a major area of concern is creep damage in high-temperature, high-energy piping. Plant engineers are faced with the challenge of implementing a cost-effective method for detecting creep damage in these operating piping systems.

Project Approach and Summary
The objectives of this project are to determine if acoustic emission can detect creep damage in low-alloy piping materials, and at what stage of damage development any detection might occur.

This project will consist of laboratory experiments to determine the science of creep damage detection via acoustic emission equipment. The acoustic monitoring test methodology will utilize procedures outlined in ASTM E1316 and E650. Large-scale creep specimens will be prepared to closely match longitudinal seam-welded components found in utility hot reheat piping. These specimens will be subjected to steady and cyclic loading to understand stress required for acoustic emission detection. Results will be targeted at longitudinal seam-welded hot reheat piping, but also will be applicable to seam-welded headers and main steam piping.

Specimens will be of a large enough size to allow for traditional NDE evaluation (ultrasonic testing [UT] and digital radiographic testing [RT]). In addition to acoustic monitoring, creep tests will be interrupted at various fractions of remaining life and evaluated using available NDE and metallurgical methods to determine the level at which damage is first detectable with each method. If possible, a correlation between the traditional NDE methods used (RT, time-of-flight-diffracton [TOFD], and phased array) and acoustic emission will be developed.

The initial investigation will be concentrated on subcritical post-weld heat treated (PWHT) welds; however, normalized welds will be added if additional support is realized.

Benefits
This project will verify cost-effective monitoring methods for inspecting seam-welded, high-energy piping systems.
Non-Destructive Methods for Detection of High-Temperature Damage in Creep Strength Enhanced Ferritic Steels (071858)

Background, Objectives, and New Learnings

High-temperature components in boilers and piping traditionally have been fabricated from chromium molybdenum steels. These low-alloy steels, commonly referred to by their ASTM designations (Grade 11, Grade 12, and Grade 22), provide good creep resistance up to temperatures of about 1050°F (550°C).

But recently, steels such as Grade 91 and Grade 92, which are more complex, have been used in these applications. The increased use of these steels has been justified by their greater strength, which allows components to operate at higher metal temperatures. Even when the temperature of operation is not increased, the greater strength allows components to be made with lower thicknesses. Thinner components reduce weight and reduce the risk of damage due to cycling. However, the additional complexity of the steels necessitates greater vigilance and control of all manufacturing and heat treatment operations.

Project Approach and Summary

A workshop will be held with utility staff, NDE service providers, and research organizations. The specific challenges associated with damage development in Grade 91 and 92 steels will be discussed, and options for detection will be considered.

After review of proposals and selection of contractors, a project kickoff meeting will detail the work to be performed. This is expected to include:

- Task 1 - Develop samples to different known levels of damage. These samples will include both base metal and welds. The actual damage will be documented using destructive laboratory test techniques.
- Task 2 - Examination of samples using advanced electromagnetic methods. Selected approaches will be applied on small samples available from previous work and from the samples developed in this project.
- Task 3 - Examination of samples using advanced ultrasonic methods. Selected approaches will be applied on small samples available from previous work and from the samples developed in this project.

Benefits

Difficulties associated with detection of damage at an early stage in Grade 91 steel already have resulted in unplanned component failures. This project will examine the ability of different approaches for detection of creep damage in Grade 91 and 92 steels and will provide specific guidelines on the advantages and limitations of different methods for detection of in-service damage.
Boiler and Turbine Steam and Cycle Chemistry - Program 64

Program Overview

Program Description

Safety and availability loss due to failures are two key issues driving R&D on major fossil power plant components, especially in older plants. Operators need to minimize major causes of lost availability and associated maintenance costs related to corrosion and inadequate cycle chemistry, and prevent boiler tube and turbine blade/disc failures and flow-accelerated corrosion (FAC).

The Electric Power Research Institute’s (EPRI’s) Boiler and Turbine Steam and Cycle Chemistry Program (Program 64) offers guidelines, technology, and training materials to help plant operators manage water-steam chemistry, reduce unplanned outages and operations and maintenance (O&M) costs, and improve unit economics.

Research Value

The industry needs to balance the risks and costs of the largest, most costly equipment, and focus on using proven technologies to create solutions. By using the results of the R&D in this program, members can:

- Improve overall unit availability — losses due to improper chemistry have a 1% or more effect on unit availability
- Reduce steam turbine efficiency losses — chemical and metallic oxide deposits reduce turbine efficiencies by up to 2%
- Reduce chemistry-related boiler tube failures
- Reduce incidence of FAC damage and failures — FAC is both a personnel safety and component availability concern
- Reduce chemistry-related O&M costs
- Improve world-class or excellent cycle chemistry

Approach

Cycle chemistry guidelines, technologies, and training materials support efforts to minimize operating risks associated with corrosion and deposition. Technical tools developed through this program include unit-specific chemical treatment methods, operating limits, and monitoring guidelines to improve plant availability, efficiency, and startup times.

- The project on cycle chemistry guidelines and technology addresses the critical aspects of fossil plant cycle chemistry and is applicable to all plant designs. Research in this area covers boiler and feedwater treatments, shutdown/startup/layup, condensate polishing, makeup, instrumentation, chemical cleaning, copper, air-cooled condensers, and FAC. Members can benchmark their chemistry programs independently or in collaboration with EPRI staff to identify areas of deficiency and determine the approximate costs (lost value).
- The project on cycle chemistry and corrosion control in the Phase Transition Zone (PTZ) provides a deterministic model to control the corrosion process of turbine materials in the PTZ. This model considers system variables such as the steam environment, liquid film composition, stress, and temperature. Monitoring and treatment of the early condensate environment provide reduction of the active corrosion and opportunities to improve thermodynamic efficiency. Members can apply the turbine damage model development work to assess risk levels in all steam turbines and identify actions needed to reduce or prevent further increases in risk levels or enhance conditions in the PTZ.
- The project on deposition in water and steam cycles addresses deposition concerns for each major plant component. Scientific and plant-based knowledge, combined with basic laboratory and field studies, provides probabilistic risk models for assessing the impact of deposits and a maintenance cleaning
activity model for removing deposited material. Members can use these models to identify the specific actions needed to address deficiencies consistent with individual unit characteristics. Application of risk assessments provides managers with the tools to evaluate conditional situations in an informed and cost-effective manner.

- Feedwater filtration and condensate polishing technology R&D develops user guidelines for assessing, selecting, justifying, and operating condensate polishing and filtration systems used to remove dissolved and suspended solids from feedwater, ensuring continual high purity of the water/steam cycle. Maintenance of high purity is essential for reducing corrosion and deposition in the cycle. Members can use the Fossil Plant Feedwater Guidelines for technical evaluations of polishing and filtration requirements and to appraise system performance.

- R&D for cycle chemistry instrumentation, control, and monitoring develops instrumentation and validates instrumentation results needed for on-line monitoring, which provides the most comprehensive approach to surveillance and control, especially in older plants and plants with reduced staff size and experience. Chemistry surveillance technology can allow members to make knowledgeable decisions about the right chemistry instrumentation and controls to protect various cycle components and improve current plant operations. Data validation methodology provides techniques for correlation and interpretation of data in a meaningful manner to assess both the plant conditions and the accuracy of monitoring data.

- Research involving corrosion in the boiler and water/steam cycle uses scientifically based criteria to determine action levels needed to prevent boiler corrosion and identifies specific actions needed to address deficiencies leading to flow-accelerated corrosion in high-energy piping and air-cooled condensers. Members can use the guidelines developed from these activities to identify specific actions needed to address deficiencies consistent with individual unit characteristics.

Accomplishments
Cycle chemistry guidelines, technologies, and training materials support efforts to minimize operating risks associated with corrosion and deposition. Technical tools developed through this program include unit-specific chemical treatment methods, operating limits, and monitoring guidelines to improve plant availability, efficiency, and startup times. Recent accomplishments include:

- Complete set of cycle chemistry guidelines for all fossil plants and cycle chemistry treatments
- Model for the corrosion and deposition process in boiler waterwalls
- Advancement in the understanding of high-temperature oxides in supercritical waterwall tubes
- Solvent evaluation and interim guidelines for chemical cleaning of supercritical steam generators
- Interim guidelines to address air-cooled condensers
- Assessment and interim guidance for the application of amine chemistries in fossil plants
- Modeling of corrosion product transport in the feedwater cycle
- Guidelines for make-up water treatment
- Cycle chemistry instrumentation selection and data validation
- Interim research on two-phase FAC in feedwater heaters and heater drains
- Benchmarking processes to assess plant or system chemistries

Current Year Activities
The program R&D for 2012 will focus on reducing corrosion damage associated with FAC and boiler deposits. Specific efforts will include:

- Comprehensive Chemistry Guidelines for all Fossil Plant Boiler and Feedwater Treatment report
- Management of Porous Deposits for Reducing Deposit-Related Corrosion report
- Flow-Accelerated Corrosion Mitigation and Monitoring report
- Chemistry Guidelines for Open Cooling Water Systems report
- Online and in situ instrumentation to monitor corrosion and FAC in the plant cycle
- Corrosion and the role of acetates and formates in the PTZ
- Enhanced Chemical Instrumentation Monitoring report
- Management of Boiler Chemical Cleaning Wastes report

**Estimated 2012 Program Funding**

$3.0M

**Program Manager**

James Mathews, 704-595-2544, jmathews@epri.com

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**Summary of Projects**

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>P64.001</td>
<td>Cycle Chemistry Guidelines and Technology</td>
<td>This project provides a comprehensive suite of guidelines, addressing the critical aspects of fossil plant cycle chemistry, and encompassing boiler and feedwater chemistry treatments, transient operating and outage conditioning, chemical cleaning, condensate polishing, makeup water treatment, instrumentation and control, copper metallurgy, and flow-accelerated corrosion (FAC).</td>
</tr>
<tr>
<td>P64.002</td>
<td>Cycle Chemistry and Corrosion Control of Turbine Materials in the Phase Transition Zone</td>
<td>This project develops modeling, technologies, and processes to reduce turbine blade and disc rim cracking due to corrosion fatigue and stress corrosion cracking in the phase transition zone (PTZ).</td>
</tr>
<tr>
<td>P64.003</td>
<td>Deposition in the Water/Steam Cycle</td>
<td>This project develops information and technologies to understand and reduce deposition on turbine blades and in feedwater and condensate systems.</td>
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<tr>
<td>P64.004</td>
<td>Feedwater Filtration and Condensate Polishing Technology</td>
<td>This project continues research to develop guidelines for selection of technologies to address the optimization of condensate and feedwater quality and purification.</td>
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<tr>
<td>P64.005</td>
<td>Cycle Chemistry Instrumentation, Control and Monitoring</td>
<td>This project develops new methods and technologies for monitoring of cycle chemistry, corrosion, corrosion product transport, and deposition activity.</td>
</tr>
<tr>
<td>P64.006</td>
<td>Corrosion in the Boiler and Water/Steam Cycle</td>
<td>This project examines boiler and water/steam cycle corrosion under a variety of operating conditions to discover causes and develop methods to prevent corrosion and incorporate them in operating guidelines.</td>
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</tbody>
</table>
P64.001 Cycle Chemistry Guidelines and Technology (069176)

Key Research Question
Cycle chemistry program deficiencies at the organizational and plant levels directly and negatively affect fossil plant unit availability, reliability, and performance. Flow-accelerated corrosion (FAC) and boiler corrosion fatigue (CF) damage mechanisms from improper chemical control are major safety concerns as well as a source of equipment failures. EPRI surveys indicate guidance in the proper application and the transfer of knowledge of cycle chemistry technologies provide a major benefit to plant operations, chemistry, maintenance, engineering, and management staff in the development of efficient and effective cycle chemistry programs.

Approach
This project is dedicated to establishing state-of-the-art guidelines for use by fossil plant chemists and operators worldwide. EPRI benchmarking activities have demonstrated the value of good chemistry to those plants and organizations with programs rated as world-class or very good. This comprehensive suite of guidelines addresses the critical aspects of fossil plant cycle chemistry and encompasses boiler and feedwater chemistry treatments, transient operating and outage conditioning, chemical cleaning, condensate polishing, makeup water treatment, instrumentation and control, copper metallurgy, and FAC. The guidelines are applicable to all fossil plant designs, including chemistry guidance for designing and operating new fossil plants for high reliability by incorporating essential features needed to avoid chemistry-related boiler tube failure (BTF) and corrosion failures in the PTZ of steam turbines and FAC.

Technology advances address the key damage and failure mechanisms in water-cooled and air-cooled condensers and feedwater heaters. The key chemistry guidelines are continuously improved using the results from other program projects, findings of EPRI Technology Innovation (TI) activities, and experience of the program members. Major planned activities include updated guidance on all chemistry treatment practices, deriving methodologies for managing and controlling corrosion product transport and boiler deposits, validation of chemistry monitoring and liquid film conditions in the early condensate of the steam turbine PTZ, assessing nanofiltration technologies for feedwater applications, and developing on-line instrumentation and enhanced instrumentation techniques for boiler and turbine corrosion.

This project provides training materials to support the development of cycle chemistry programs to specifically address:
- Cycle chemistry improvement to optimize boiler, feedwater, and steam chemistries.
- Flow-accelerated corrosion (FAC) to mitigate/eliminate this damage mechanism, which is a major safety concern.
- Condenser and heater tube failure control.
- Turbine steam chemistry and PTZ corrosion control

This project also supports a tri-annual International Conference on Cycle Chemistry, as well as other conferences, seminars, and member user groups.

Impact
- Establishes the de facto standard of worldwide chemistry practices
- Can be used to significantly improve fossil unit availability and performance
- Eliminates chemistry-related damage in high-pressure piping, boilers, and turbines
- Reduces levels of maintenance activities compared to those required with deficient chemistry
- Provides unparalleled practical knowledge and understanding of the scientific basis of significant cycle chemistry processes and corrosion mechanisms
How to Apply Results

Each member will customize the EPRI approach to specific plants and units, using the guidelines and reports provided as resources. Members can benchmark their chemistry programs independently or in collaboration with EPRI staff to identify areas of deficiency and determine the approximate costs (lost value). The content of the various guidelines can be used to identify specific actions needed to address these deficiencies. For example, the chemistry guidelines can be consulted to verify proper selection and optimization of feedwater and boiler water chemistry used in individual fossil units. The benchmarking process or other means of unit assessment should be repeated periodically as a means of checking the overall impact of improvements.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td><strong>Open Cooling System Chemistry Guidelines:</strong> This project will develop a revised guideline</td>
<td>12/31/12 Technical Report</td>
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<td>in collaboration with the Nuclear Water Chemistry Group on the Chemistry in Open Cooling</td>
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<tr>
<td>Systems. The Guidelines for Fossil and Nuclear Plants will be updated to the current state</td>
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<td>of knowledge of scientifically based information and compiled into a comprehensive guideline,</td>
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<td>incorporating best practices, guidance on using chemicals to treat microbiological growth,</td>
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<td>macrobiological growth, corrosion, and suspended solids fouling and scaling in service water</td>
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<td>and cooling systems. Monitoring and control methodologies as well as specific chemical treat</td>
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<td>ment regimes will be covered.</td>
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| **10th International Conference on Cycle Chemistry in Fossil and Combined Cycle Plants with** | 12/31/12 Workshop, Training, or Conference |
| **Heat Recovery Steam Generators:** This international conference will be held in Seattle, |
| WA. June 25-29, 2012. The conference will provide the industry with the latest information, |
| developments, and field experience in all aspects of fossil plant chemistry. In addition to |
| presentations from world experts and utility experience reports, this conference will provide |
| access to at least two technology transfer workshops.                                        |

Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Guidelines for Chemical Cleaning of Fossil and HRSG Plant Equipment:</strong> This project will</td>
<td>12/31/13 Technical Report</td>
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<td>develop revised guidelines, reflecting the spectrum of technology and best practices for</td>
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<td>chemical cleaning of plant equipment. Specifically, the guidelines will focus on</td>
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<td>methodologies to assess the need to chemically clean the boilers and evaporators of</td>
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<td>HRSGs, as well as high-pressure turbines, water-cooled generator stators, water-cooled</td>
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<td>condenser tubes, and other ancillary systems. This revision will include the latest</td>
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<td>information and research on solvent selection, specifically for removal of high-temperature</td>
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<td>oxides and water-borne oxides in supercritical units, and methods of waste disposal to meet</td>
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<td>the increasingly stringent water and air quality standards. The final report will provide</td>
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<td>the station chemist, maintenance engineer, environmentalist, and plant management with a</td>
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<td>complete guide to chemically cleaning plant process equipment, determining when cleaning is</td>
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<td>required, and details of the chemicals and processes for a safe, effective, and</td>
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<td>environmentally responsible cleaning.</td>
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P64.002 Cycle Chemistry and Corrosion Control of Turbine Materials in the Phase Transition Zone (100508)

Key Research Question
Since the early 1990s, incidents of turbine blade and disc rim cracking due to corrosion fatigue and stress corrosion cracking in the phase transition zone (PTZ) have increased, causing unit availability losses and significant increases in plant maintenance costs. Understanding of the composition of steam and liquid films in the PTZ is fundamental to both deposition on component surfaces and nucleation of steam in the PTZ. Based on a decade of EPRI Technology Innovation (TI) work and six years of work in Program 64, a deterministic model of the corrosion process in the PTZ was developed. TI R&D is closing the gap between pit initiation and crack development. A state-of-knowledge document on corrosion fatigue and stress corrosion cracking in the turbine environment has been developed.

Approach
The model of the corrosion process in the PTZ considers system variables such as the steam chemistry environment, liquid film composition and electrochemical properties, stress, temperature, and conductivity. In 2006, additional project activity sponsored by Programs 64 and 65 began to develop a new EPRI code for “Corrosion in the PTZ.” This work involves validating the interim model with case studies, then fine-tuning it using the results of corrosion tests conducted in liquid films and crevice environments to determine the pitting potential on the blade/disc surfaces.

This project supports further development, including derivation of the necessary evolutionary path algorithms for the chemistry and operation, and field testing of monitoring devices to supply or supplement online information for the PTZ code. Data resulting from this work will be used to refine the model and provide plant owners, engineers, operators, and chemists with the guidance and tools to optimize the turbine operation and steam environment, control corrosion of the turbine material in the PTZ, and assess life predictions and maintenance schedules. Important research findings also will be incorporated in future versions of the key EPRI Chemistry Guidelines (64.001) and training materials.

Impact
- Minimize the risk of stress corrosion cracking and corrosion fatigue damage to steam turbines
- Improve steam turbine availability
- Reduce future steam turbine maintenance costs by avoiding chemistry-related damage and failures
- Improve LP turbine efficiency

How to Apply Results
Members can apply the turbine damage model development work to assess risk in all steam turbines and identify actions needed to reduce or prevent further increases in risk levels. Data pertaining to past failure incidents can be reviewed in collaboration with EPRI for possible uploading to the model. Installation of the instrumentation now under development on working steam turbines can provide real-time indications of environmental conditions in which turbine damage is active and significant. Members using the application of new chemical treatment processes or chemicals, such as neutralizing amines and polyamines, could realize substantial improvement in corrosion protection and efficiency, if not power production, in the LP region of the steam turbine.
## 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Control of Corrosion in the Steam Turbine PTZ - Progress Report: EPRI's Life Predictions within the Steam Turbine PTZ will be used to establish risk assessments of discrete steam environments and operating conditions. To control the corrosion mechanism in the PTZ, researchers will evaluate the potential for modifying the actual conditions and environments utilizing steam-modifying agents (such as amines), and will assess the efficacy of EPRI monitoring techniques. The initial work will focus on the application methods for modifying steam chemistries and monitoring the effect on the early condensate and the corrosion mechanisms within the PTZ. Working with Program 65, the project will use pitting monitors or sacrificial test strips to measure success.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>

| Technical Update: State of Knowledge of Acetate and Formate Corrosion Behavior in the Turbine Phase Transition Zone: This project will provide an update of current knowledge and identify gaps in the understanding of the transport behavior of acetate and formate and similar weakly acidic compounds in the turbine steam environment. It will outline the current understanding of the chemistry, transport, distribution, volatility and solubility, concentrating mechanisms, and the influence of accumulation and concentration in the liquid films in the turbine phase transition zone on turbine corrosion fatigue and stress corrosion cracking. The project will seek to address gaps and/or deficiencies in the current knowledge with supplemental research on the role of acetate and formate in turbine damage mechanisms, as well as to determine the appropriate limits for the individual species. The update will provide the power plant chemist and turbine engineer with a guide for establishing steam limits specific to applications of alternative chemical treatments such as volatile amines. | 12/31/12 | Technical Update |

## Future Year Products

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<tr>
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<tbody>
<tr>
<td>Control of Corrosion in the Steam Turbine PTZ - Final Report: Building on the research conducted in 2012 on controlling corrosion in the PTZ, modification of the chemistry of the early condensate and EPRI monitoring techniques will be developed to control the corrosion mechanism in the PTZ. Working with Program 65, the project will use pitting monitors or sacrificial test strips to measure the success. The EPRI Model for Life Predictions within the Steam Turbine PTZ will be used to establish risk assessments of discrete steam environments and operating conditions.</td>
<td>12/31/13</td>
<td>Technical Report</td>
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</table>

| State of Knowledge: Turbine Steam Chemistry and Control: This project will outline the fundamental bases for EPRI Turbine Steam Chemistry Control, and the current knowledge on the transport and behavior of impurities in the turbine steam environment. It will outline the current understanding of the chemistry of water and steam, steam quality and impurity transport, chemical distribution, volatility and solubility, deposition mechanisms, influence of deposits, and turbine corrosion. The report will include the new understandings from recent research on inhibition of crevice and pitting corrosion, the influence and behavior of acetate and formate on corrosion mechanisms, and the control of corrosion in the phase transition zone. The final report will provide the power plant chemist and turbine engineer with a guide to the fundamental chemistry mechanisms that occur across the turbine steam flow path of fossil power plant cycles. The project also will identify potential future research needs in the field of turbine steam chemistry and control. | 12/31/13 | Technical Report |
P64.003 Deposition in the Water/Steam Cycle (100509)

Key Research Question
Despite its critical influence on plant efficiency and availability, deposition of oxides and impurities around the fossil plant fluid cycle is not completely understood. Better knowledge of deposition on boiler waterwalls and steam turbines could improve fossil unit availability and performance. This is a major concern because deposits are a precursor to a number of chemistry-related damage mechanisms. Deposits also have a detrimental impact on component efficiency and performance. Deposition information is required for each major plant component around the cycle. Maintenance cleaning activities to remove deposited material increase unit operating costs and extend the interval of unit outages. EPRI has compiled scientific and plant-based knowledge, and conducted initial basic laboratory and field studies, to understand and reduce deposition on turbine blades.

Approach
This project has conducted laboratory studies on a high-heat flux deposition rig to simulate boiler water containing iron and copper oxides under oxidizing and reducing conditions. Over the last five years, work has been conducted to better understand the structure of drum boiler waterwall deposits, and to support ongoing efforts to construct a deterministic model, including a risk-based assessment of the environmental condition and the impact of deposition on corrosion.

With the culmination of understanding of the deposition mechanics and influences on corrosion, this project will continue to assess methodologies and chemistry practices to manage deposits and lower their impact on unit performance and material damage.

Deposition in steam turbines, feedwater, and condensate systems also will be addressed, and local material solutions developed. Copper deposition in some high-pressure turbines remains a problem, which will continue to be addressed in case studies as requested by members.

Impact
- Improve cycle chemistry guidelines through a better scientific understanding of corrosion and deposition in fossil units
- Improve guidelines for managing deposition and determining when to chemically clean boilers
- Apply improved guidance to avoiding deposition-related performance losses in steam turbines
- Apply scientifically sound approaches to defining boiler chemistry and deposition limits
- Provide scientifically based risk assessment of corrosion and deposition and environmental factors of cycle chemistry

How to Apply Results
The results of this work will be incorporated into the next series of EPRI guidelines, which members can use to identify the specific actions needed to address deficiencies in individual unit characteristics. For example, the chemistry guidelines can be consulted to verify proper selection and optimization of feedwater and boiler water chemistry used in individual fossil units. Risk analysis can be used to make informed decisions regarding operating damage and cost — for example, cost assessments associated with continued operation with known upset chemistry conditions and corrosive environments.
2012 Products

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tr>
<td><strong>Management of Porous Deposits: Field Demonstration:</strong> The methodologies and treatments with potential to control and reverse porous deposit formations will be applied in field demonstration project(s). This project will evaluate the effectiveness of the techniques developed to manage the growth, thickness, maturation, and porosity of deposits in actual field applications on operating fossil power units. It will assess the pre-application condition of porous deposits present in the field unit; the application and monitoring of the deposit management techniques; and the quantification of the effectiveness of the technique to control and/or reverse deposition based on subsequent porous deposit condition assessment. The final report will provide refined guidance on the application of the methodologies and treatment based on actual field experience, as well as an assessment of the effectiveness of the various techniques for management of porous deposits.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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</table>

| **Management of Boiler Chemical Cleaning Waste:** This project will review and summarize the current chemical cleaning treatment formulations and disposal options available. This project will provide a revision to the EPRI Boiler Chemical Cleaning Waste Management Manual, 1992, TR-101095. Significant changes in the practices and solvent used for boiler cleanings, as well as the waste management practices, necessitate a timely revision of the waste management manual. The continued evolution of air, water, and solid waste regulations have greatly altered the choices available for boiler cleaning waste management options. Environmental concerns are resulting from the disposal of chemical cleaning waste, which is becoming more difficult and expensive to achieve. The project also will investigate new treatment formulations/technologies and their impact on future disposal practices. | 12/31/12               | Technical Report      |

**P64.004 Feedwater Filtration and Condensate Polishing Technology (046583)**

**Key Research Question**

High-purity feedwater is critical to control damage-causing deposition and corrosion in the feedwater cycle, boiler, and turbine. Boiler waterwall deposits primarily consist of particulates in the form of metal oxides transported from the feedwater. Oxide transport is of particular concern in units that cycle or in which the cycle chemistry has not been fully optimized. Ionic contaminants to the feedwater cycle from poor-quality or nonoptimized makeup water treatment and in-leakage of cooling water or other sources are the fundamental corrodicts leading to boiler tube hydrogen damage and turbine stress corrosion and corrosion fatigue cracking. Existing technologies require innovative approaches to continue optimization of the operating costs and performance of these systems. Issues of concern are operation at elevated temperatures; fouling and pressure drop; premature exhaustion on high pH or high CO₂ levels; and chemical and materials costs.

**Approach**

EPRI research studies on condensate polishing and feedwater filtration confirm that applying these technologies is a means of removing dissolved and suspended solids from the feedwater; however, improvements are needed to optimize the operating costs and performance of these systems. In 2008 and 2010, Technology Innovation (TI) projects focused on assessing the current state of carbon nanotube water filtration technologies, which have shown the potential application of nanofiltration for supplementing filtration and polishing system performance. Continued research will be used to develop guidelines for selection of established and emerging technologies to address the optimization of condensate and feedwater quality and purification.
Impact

- Eliminate dissolved ionic contamination to the water/steam cycle
- Facilitate optimization of the cycle chemistry with alternative treatments or higher-pH operation
- Reduce metal oxide transport to boilers
- Extend time interval between boiler cleanings
- Reduce efficiency losses associated with boiler tube deposits
- Eliminate boiler corrosion and boiler tube failures associated with boiler tube deposits

How to Apply Results

The Polishing and Filtration Guidelines and Technical Assessments can be used by members for technical evaluations of polishing and filtration requirements, and optional methodologies. Members can assess the needs and benefits from the application and installation of these cleanup systems using Risk-Based Technologies (P64.003) and Life Prediction Models (P64.002), in association with Comprehensive Cycle Chemistry Guidelines (P64.001), to appraise system requirements and savings.

P64.005 Cycle Chemistry Instrumentation, Control and Monitoring (062000)

Key Research Question

Long-term fossil unit availability requires effective control of cycle chemistry. Online monitoring provides the most comprehensive approach to surveillance and control. Automated approaches to chemistry control are increasingly important in older plants and plants with reduced staff size and experience. Water chemistry analyzers typically require care and attention to ensure that suitably conditioned samples are provided and that precision and bias errors associated with the instruments used are recognized and minimized. Instrumentation provides a characterization of the chemistry environment of bulk fluid conditions. Comparison of measured chemistry readings to target values and action levels provides a useful — though indirect — assessment of the risk of damage to components touched by water and steam. Research is needed for the development of both instrumentation and validation of instrumentation results that provide direct indications to operators of the impacts of the chemistry.

Approach

EPRI’s designated core level of instrumentation provides adequate surveillance and control. Although it is recognized that many organizations find it difficult to provide and maintain the full suite of instrumentation indicated in current guidelines, core instrumentation is essential to meet the plant chemistry needs. A cycle chemistry instrumentation and control state-of-knowledge report was completed in 2007, with a complementary instrumentation data validation report completed in 2010. This project will ensure the quality of the data provided by the instruments.

Current monitoring methods provide only indirect indications of corrosion, corrosion product transport, and deposition activity. Methods that could provide direct assessments of chemical activity and could be used to help plan inspection, sampling, and maintenance activities such as chemical cleaning, would be more useful tools. This follow-up R&D will examine research for chemistry surveillance technology advances consistent with plant needs. Future work will address chemistry instrumentation and control needs for protection of various cycle components, including methods for managing and utilizing the data generated.

Impact

- Ensure reliable operation of existing chemistry instrumentation
- Provide validation for new and existing monitoring methods
- Understand instrumentation requirements to support future chemistry guidelines
- Improve the basis for chemistry control instrumentation improvements
How to Apply Results

Chemistry surveillance technology development can allow members to make knowledgeable decisions about the right chemistry instrumentation and controls to protect cycle components and improve current plant operations.

2012 Products

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<tr>
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<tr>
<td><strong>Online Chemistry Data Management System:</strong> This project will review online data management systems with a team of fossil chemistry users to assess the needs and requirements of cycle chemistry. This report will detail the logic to be applied for assessing each measured parameter in combination with all other monitored points for early identification of chemistry excursions, prevention of corrosion damage and deposition problems, and evaluation of cycle performance. The report will provide expert advice and corrective operating procedures. Members will use this information to develop internal cycle chemistry advisory systems integrated into a plant’s control system, or engage in a supplemental project to develop plant-specific systems with EPRI assistance.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>In-situ Monitoring or Indicating Flow Accelerated Corrosion:</strong> This project will continue the two-year exploration of the use of in-situ/ex-situ techniques for real-time monitoring of corrosion rates, and specifically single-phase FAC, in selected environments. In-situ monitoring techniques, including the use of electrochemical corrosion potential and corrosion resistance probes, will examine actual or simulated FAC activity in corrosion-prone materials, environments, and geometries. Ex-situ monitoring techniques will be examined in parallel for comparison of these methods. A report of the findings will provide an evaluation of the potential use of these methods in power plant applications for monitoring FAC.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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Future Year Products

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<td>07/31/13</td>
<td>Technical Report</td>
</tr>
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</table>
**Field Evaluation of In-situ Side Steam Monitoring for Flow Accelerated Corrosion:** This project will conduct field studies using the in-situ/ex-situ techniques developed for real-time monitoring of single-phase FAC. Side-stream studies of fossil and HRSG power plant systems susceptible to single-phase FAC will be conducted to examine actual FAC activity in corrosion-prone materials, environments, and geometries. The findings of the field evaluation will be compared with NDE measurement and system operating chemistries as well as ex-situ monitoring techniques. A report of the findings will provide an evaluation of the potential use and benefit in power plant applications for monitoring and controlling FAC.

**P64.006 Corrosion in the Boiler and Water/Steam Cycle (058176)**

**Key Research Question**

Boiler waterwall internal corrosion is the leading corrosion-related cost in the fossil power industry. EPRI treatment guidelines provide boiler water corrosion control based on cation conductivity, which has been shown to minimize corrosion without providing a direct indicator of the corrosion process. Scientifically based limits, established to practically eliminate the causative environment and conditions of corrosion, provide for proper guidance and control of boiler corrosion. Flow-accelerated corrosion (FAC) — both single- and two-phase — still is a major damage mechanism occurring too frequently in power plants. Units with air-cooled condensers are displaying corrosion resembling FAC, as detailed in the interim guideline produced in 2008; however, the mechanism is not understood.

**Approach**

Since 2006, this project has measured boiler corrosion under simulated boiler corrosion conditions using all-volatile treatment (AVT) and phosphate continuum (PC) with levels of chloride contamination. Continuing work has sought to define the limits in a simulated deposit medium using electrochemical corrosion potential measures. For the first time, EPRI established action levels to prevent corrosion and incorporate them in the next revisions of the operating guidelines (P64.001). The final step in developing more realistic boiler water contaminant control curves was to use the limits derived in this project in the final deposition rig tests (P64.003).

To address conditions of two-phase FAC, simulated models will evaluate the conditions of influencing FAC and provide information on conditions for stifling the mechanism. The findings will be invaluable in establishing control methodologies to mitigate and eliminate two-phase FAC as it is occurring in feedwater heater steamside drains, low-pressure HRSG evaporators, and air-cooled condensers.

**Impact**

- Reduce major O&M costs
- Establish probabilistic risk associated with boiler waterwall corrosion
- Improve reliability by minimizing or eliminating internal boiler waterwall corrosion in drum boilers
- Apply scientific basis to boiler chemistry control guidelines
- Reduce the occurrence of two-phase FAC in all prone areas in fossil plants and HRSGs
- Reduce corrosion and corrosion product transport in air-cooled condensers

**How to Apply Results**

Members can use the guidelines to identify specific actions needed to address deficiencies consistent with individual unit characteristics. For example, the guides to control boiler corrosion will help members improve reliability by using suggested actions to minimize or eliminate internal boiler waterwall corrosion in drum boilers. Control methodologies can be applied to minimize two-phase FAC in feedwater heater drains.
## 2012 Products

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<td><strong>Investigation of Flow-Accelerated Corrosion Under Two-Phase Flow Conditions:</strong> This project continues a three-year research effort involving two-phase FAC conditions in a simulated test loop and will provide details and greater understanding of the mechanism and control factors. Using a simulated laboratory environment, this work will evaluate methods for mitigating two-phase flow-accelerated corrosion typically found in the steamside of feedwater heaters and associated drain lines of conventional fossil fired units, and in HRSG low-pressure (LP) economizer evaporator tubes. The focus of the work will be to quantify the effectiveness of varying methods to control/mitigate two-phase FAC in the test loop with the goal of developing mitigation methods for implementation in field trials.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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## Future Year Products

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<tr>
<td><strong>Field Validation of Two-Phase Flow Accelerated Corrosion Control:</strong> This project will apply techniques and methodologies, identified through laboratory research to mitigate two-phase flow accelerated corrosion in critical areas of the power plant or HRSG, to actual plant equipment in the field. Monitoring techniques in the susceptible two-phase FAC areas will be utilized to measure the rate of material wastage compared with nonoptimized treatment methods. A successful study will demonstrate a marked reduction or elimination of the FAC mechanisms, thereby improving reliability of equipment, increasing service life, and increasing personnel safety.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>State of Knowledge: Corrosion Mechanisms in Water and Steam Cycles of Fossil Plants:</strong> This project will be a concise summary of the current knowledge and understanding of corrosion mechanisms present in water and steam cycles of fossil plants. It will review the current state of knowledge of boiler, feedwater, condensate, and steam corrosion, including all the steamside/waterside corrosion-influenced failure modes. It will discuss the latest understanding of general corrosion mechanisms, such as single-phase and two-phase FAC, first-formed condensate corrosion (FCC), and low- and high-temperature corrosion phenomena. The final report will provide the station chemist and plant management with a complete guide to corrosion processes in fossil plants. In addition, the project will identify the limits of understanding for each corrosion mechanism and possible needs for future research efforts.</td>
<td>12/31/13</td>
<td>Technical Report</td>
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Supplemental Projects

Corrosion Mechanisms in Air Cooled Condensers (071854)

Background, Objectives, and New Learnings
Air-cooled condensers (ACCs) increasingly are being installed to reduce water use in power plants. Unfortunately, significant iron corrosion product transport has been exhibited in ACCs on numerous units, which is not unique to any specific design. EPRI established interim guidelines for control of steamside corrosion in air-cooled condensers. This work (detailed in EPRI document 1015655) found that the active corrosion mechanisms in the ACC requires further study to establish effective comprehensive chemistry control guidelines. This project will explore additional techniques for mitigating corrosion product concurrent with research of the corrosion mechanism(s).

Project Approach and Summary
This project will research the mechanisms of corrosion observed in the air-cooled condenser and evaluate treatment strategies to mitigate damage and reduce iron transport. Research laboratory studies will be developed to simulate and understand the key factors involved in the corrosion process. The project at host utilities will evaluate treatment technologies and monitoring tools such as nondestructive evaluation (NDE), analysis of corrosion product transport (CPT), along with wet chemistry, and visual inspections. The project will monitor corrosion transport throughout the water and steam cycle to determine the improvement benefit in other key unit components such as in-line polishers and condensate filtration systems.

Benefits
Improved understanding and control of the active corrosion mechanisms in the ACC can result in longer component life and reduced losses due to downstream impacts of corrosion products transported from the ACC. This project will provide utilities with improved techniques to control and manage these conditions. Mitigation of the corrosion mechanisms in the ACC will reduce the impact of deposition on heat exchange surfaces throughout the cycle. Improved performance, reduced damage, and reduced O&M cost are direct benefits. Extended filtration and polisher service periods with lower operating cost also are anticipated.
Program Overview

Program Description
Up to 70% of outages planned for steam power plants involve work on the turbines. Power producers continually seek ways to optimize operation and maintenance activities on aging turbine-generator fleets. These activities can reduce maintenance costs, improve component reliability, and increase generator output. However, maintaining a detailed awareness of effective maintenance techniques is challenged by evolving operating experience, advanced materials and upgrade options, reduced staffing levels, and the retirement of experienced personnel.

The Electric Power Research Institute’s (EPRI’s) Steam Turbines-Generators and Auxiliary Systems program (Program 65) develops technologies and guidelines that help fossil and nuclear plant operators optimize steam turbine and generator equipment life cycles to increase availability, shorten scheduled maintenance outages, and improve steam turbine performance. Research and technical support activities enable power plant operators to reduce operation and maintenance costs, maximize plant performance, and more effectively implement plant upgrades and asset management strategies.

Research Value
Using an integrated approach that incorporates work from related EPRI programs, this program focuses on reducing operations and maintenance (O&M) costs, managing risk, maximizing plant performance, providing technical support for plant staff, and producing information to support upgrade studies and asset management strategies. Research results inform decisions regarding run/repair/replace and provide detailed guidance for planning and performing critical overhaul and maintenance activities.

By participating in this program, plant operators can obtain information that they can use to:
- Reduce maintenance costs
- Maintain high availability
- Lower operating and regulatory risks
- Implement cost-effective thermal performance improvements
- Extend component life
- Increase staff technical expertise and awareness of industry issues

Involvement in the program will help:
- Educate participants about worldwide turbine-generator (T-G) issues and solutions
- Provide opportunities to share information with industry experts, engineers, major T-G original equipment manufacturers (OEMs), and vendor/service providers worldwide

Approach
The program portfolio includes generating guidelines; analyses of the effects of flexible operation and unit upgrades and uprates; preventive maintenance (PM) guides and access to the EPRI PMBasis database containing more than 150 modules, including the current 18 turbine-generator modules; guidance on maintenance and repair optimization; risk assessment and advanced modeling technologies; performance assessment tools; and information exchanges, including reports, workshops, and users groups.

- Program members receive information on
- T-G outage management
- Unit maintenance intervals
- T-G outage scope
- T-G alternative repair/replacement options
Industry best practices for maintenance of turbines and generators
- Approaches and solutions to controlling corrosion in the low-pressure turbine phase transition zone (PTZ)
- Members also receive information and technologies on turbine and generator nondestructive examination
- remaining life assessment
- condition monitoring that supports risk management

Many members begin their participation in Program 65's R&D by joining the Turbine Generator Users Group (TGUG), a forum for sharing technical expertise among utilities and the six major T-G original equipment manufacturers (OEMs) worldwide. TGUG is offered as a supplemental project in Program 65. Program members also are eligible to attend the Turbine Generator User Group meetings/workshops, the EPRI Steam Turbine Generator Workshop and Vendor Exhibition, and other workshops offered by the program.

Potential projects for each subsequent year's R&D efforts are discussed with the program member advisors during the current year's third-quarter Generation advisory council meetings, where the members assist the P65 staff with prioritizing these R&D efforts. These potential projects typically are identified during the year by program members, Turbine Generator User Group discussions, and at industry events. The number of projects completed each year is based on yearly funding levels, coupled with this project prioritization list.

Accomplishments

EPRI’s Turbine-Generator program is recognized in the industry as an authoritative source for up-to-date information on T-G issues and solutions. When members have uprated/upgraded existing units, performed unit scheduled or forced outages, evaluated component conditions and associated operational risks, or educated their T-G staffs, these products have provided invaluable information and assistance:

- Staff education and training through turbine and generator workshops and seminars
- Turbine auxiliary systems maintenance guides for turbines and generators
- T-G outage reduction guidance
- T-G torsional vibration detection and mitigation
- T-G equipment and component repair and purchase specifications
- NERC regulation education and TG capability validation assistance
- T-G nondestructive evaluation (NDE) testing and application guidance
- Regular interaction with all major turbine and generator OEMs worldwide

A downloadable, comprehensive list of more than 200 current project deliverables from this T-G program is available at www.epri.com under product ID 1021425.

Current Year Activities

The program R&D for 2011 will focus on operation and maintenance costs reduction, unit and component risk management, turbine thermal performance, and the education of utility plant staff through workshops, seminars, and webcasts. Specific efforts will include:

- Continued additions to the Guidelines for Reducing Time/Cost of TG Maintenance and Overhauls CD set
- Completing Nanostructured Coatings for Improved Oxidation and Erosion of Resistance of Valve Materials Guide
- Completing Handbook for Steam Turbine and Generator Failure Identification
- Completing the Turbine Generator Auxiliary System Maintenance Guide: Vol. 7 Guide
- Completing PM Database Module Additions
- Completing Alternative Ultrasonic NDE Techniques for Detecting Fatigue-Related Material Life Consumption Guide
- Conducting two Turbine Generator User Group (TGUG) meetings with the associated winter workshop
- Conducting the 12th EPRI Steam Turbine-Generator Workshop and Vendor Exposition
- Conducting NERC Interest Group meeting as needed
- Completing a Short-term Shutdown of Steam Turbine-generators and Auxiliary Systems Guide
- Completing a Shipping Preparation and Long/short-Term Storage of Turbine and Generator Components Guide

Estimated 2012 Program Funding
$5.0M

Program Manager
Alan Grunsky, 704-595-2556, agrunsky@epri.com

Summary of Projects

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<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tr>
<td>P65.001</td>
<td>Operations and Maintenance Cost Reduction</td>
<td>This project develops guideline documents for condition assessments, outage planning, replacements, disposition of damaged components, repair techniques, corrective actions, and specific maintenance practices for turbine generators and their auxiliary systems.</td>
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<tr>
<td>P65.002</td>
<td>Risk Assessment</td>
<td>This project provides emerging technologies for turbine-generator condition and component failure risk assessments. Risk assessment technology produces failure probability data that can be combined with maintenance and replacement power costs to assess financial risk.</td>
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<tr>
<td>P65.003</td>
<td>Information Exchange for Plant Staff</td>
<td>Participation in this project's workshops and meetings allows utility personnel to quickly determine the most appropriate repair techniques, identify current industry experience and best practices in improving the reliability and availability of the unit, and transfer the technology developed by the overall T-G program into their maintenance practices systemwide.</td>
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P65.001 Operations and Maintenance Cost Reduction (052070)

Key Research Question
Reduced staffing levels and the retirement of experienced personnel have added challenges to meeting industry goals for equipment availability in the current competitive environment.

Approach
This project addresses core issues facing engineering staff today — reducing O&M costs and increasing thermal performance — by:
- Developing guidelines for T-G outage planning, disposition of damaged components, repair techniques, corrective actions, and specific maintenance practices
- Analyzing the effects of flexible operation and unit upgrades and uprates
- Producing preventive maintenance (PM) guides to include development of modules for the EPRI PMBasis Database
- Optimizing generator rotor maintenance, exciter maintenance, and retrofit and replacement guidance
Impact

- Decrease outage duration
- Increase outage intervals
- Improve repair of components
- Improve thermal efficiency
- Improve turbine-generator PM/Predictive Maintenance (PdM) process and practices

How to Apply Results

The documents produced and PM modules added to the PMBasis database can be used when a utility is faced with equipment repair or testing or component condition assessment. Members can integrate the content in these guidelines in their own procedures and training materials. The guidelines can be placed on internal networks and provide an excellent resource for continuous improvement training, as well as new-hire orientation for system owners and maintenance staff. Utilities planning new equipment purchases can take advantage of the guidelines’ content in preparing their own site-specific procurement specifications.

2012 Products

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<tr>
<td><strong>Generator Failures Handbook:</strong> The Generator Failures Handbook will, like the Turbine Failures Handbook scheduled for 2011 delivery, provide a visual guide for identifying generator failure mechanisms in a format useful to plant staff.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<td><strong>Evaluation of Flow Guide/LP Turbine Exhaust Hood Improvements:</strong> Due to recent advances in CFD modeling, the costs of designing and fabricating more efficient exhaust hoods and flow guides have decreased. This presents an opportunity for heat rate improvement as well as potential gains in reliability. This project seeks to quantify these improvements and compare them to the expected costs of engineering, fabrication, and installation.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<tr>
<td><strong>Cost-Benefit Evaluation of Admission Schemes to HP Turbines:</strong> The goal of this project is to compare partial-arc and full-arc admission schemes and evaluate the potential costs and benefits. Results of this project could include potential heat rate and reliability improvements. The effects of increased load following will be incorporated into the analysis.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<tr>
<td><strong>Use of FARO Technology in TG Maintenance Activities:</strong> CMM (Coordinate Measurement Machines) technology has evolved and shows the potential to decrease outage time and safely increase speed and accuracy of dimensional checks. This project will explore options and techniques for use of CMM. Specific applications of FARO technology, along with other CMM, will be identified and presented.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<tr>
<td><strong>PM Database Module Updates:</strong> The PM Basis Database provides a centralized resource for plant equipment failure modes to guide decisions on maintenance, monitoring, and repair</td>
<td>12/31/12</td>
<td>Software</td>
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<tr>
<td><strong>Generating Unit Voltage Ride-Through Performance Criteria (NERC RPC-024):</strong> Low-voltage ride-through (LVRT) is what an electric device may be required to be capable of when the voltage is temporarily reduced due to a fault or load change in the grid. Each Generator Owner will be required, per NERC Standard PRC-024-1, “Generator Frequency and Voltage Protective Relay Settings,” to set its installed generator over- and under-voltage protective relays not to trip during the steady-state and voltage-related operating conditions. Existing plants do not have LVRT capability as prescribed in PRC 024-1. The purpose of this project is to assess cost and benefits of attaining LVRT capability in future fossil-fueled power plants.</td>
<td>12/31/12</td>
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Additions to Turbine Valve Condition Assessment Guide: To increase the value of the Turbine Valve Condition Assessment Guide, Program 65 will work with advisors to identify additional types of valves to include in the guide, providing plant staff with information on a wider variety of turbine valves.

Guidelines for Reducing Time and Cost of Turbine-Generator Maintenance Overhauls and Inspections: Up to 70% of the outages planned for conventional steam power plants involve work on the turbine. The challenge for engineers is to improve performance and extend reliability while eliminating unproductive activities from the maintenance outage schedule. This report provides general guidelines for planning and performing maintenance on steam turbines during outages.

Demonstration of Chemical Cleaning of Valve Components: The process identified in EPRI Report 1020882 details an in-situ cleaning process that has proven effective at removing blue blush oxide deposits from valve stem material in laboratory settings. This demo project seeks to validate lab results in a field setting. Completion of this project depends on identifying a host fossil generation power plant for the demonstration and evaluation.

P65.002 Risk Assessment (052072)

Key Research Question
Risk assessment is an increasingly important aspect of both short- and long-term planning. Managing risk requires a combination of advanced inspection techniques; new nondestructive evaluation (NDE) technologies that reduce inspection time and increase accuracy; analytical tools to address component cracking; and corrosion degradation modeling.

Approach
This project provides emerging technologies for:
- Guidance in run/repair/replace decisions, plant life extension, life-cycle management, and overall optimal use of capital resources
- Turbine-generator condition assessment and component failure risk assessment
- Risk-assessment technology, producing failure probability data that can be combined with maintenance and replacement power costs to assess financial risk
- Emphasis on NDE of turbine-generator components, condition assessment, and remaining-life assessment
- Completion of advanced modeling of corrosion-assisted cracking, including delivery of a corrosion cracking prevention guide

Impact
- Accurately assess risk with plant turbine-generator upgrades and maintenance
- Investigate emerging technologies for assessing turbine-generator condition and component failure risk

How to Apply Results
The EPRI technology produced by this program can enhance the ability to analyze and quantify the risks associated with component failure, replacement, upgrades, and uprates. Members can use the information from this project to customize their turbine operations windows, in order to assess the economic impact of applying the methodologies such as those contained in the Turbine Blade Vibration Monitoring report. Access to improved inspection mockups allows members to more confidently evaluate nondestructive inspection systems and personnel.
2012 Products

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<td>Advanced Corrosion Model: A methodology will be developed for assessment of cyclic loaded components operating at high temperatures, in which creep-fatigue damage and cracking lead to failure. The ultimate goal is to develop an up-to-date, user-friendly defect assessment tool for plant engineers making run/repair/replace decisions.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>LP Rimlife Software Upgrade: Expands the capabilities of the popular LP Rimlife software to include more LP turbine rotor geometries.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
</tbody>
</table>

P65.003 Information Exchange for Plant Staff (052076)

Key Research Question

Use of EPRI material and products in members’ plants is made more difficult by decreasing staff and loss of expertise. For example, an estimated 30% of the U.S. nuclear workforce will be eligible to retire in the next five years. New employees need a much faster, more efficient method to gain knowledge of plant equipment and the problems and issues associated with operating and maintaining their equipment.

Approach

One of the most effective ways for plants to reduce operating cost is to apply the lessons that others have learned in addressing common reliability and maintenance issues. This program will help members share up-to-date information, including industry experiences, data, and turbine-generator (T-G) problems for common equipment. Participation in the Turbine Generator User Group, the T-G Technology Transfer workshops, technical webcasts, and the Steam Turbine Generator Workshop and Vendor Expositions educate plant engineering staff about resources available through EPRI and the industry that can help solve their operating and maintenance problems.

Impact

- Increase turbine-generator staff expertise
- Apply other utilities’ lessons learned
- Be aware of emerging issues
- Establish and maintain direct contact with industry peers and T-G OEMs and vendors

How to Apply Results

Active participation in the Turbine Generator User Group and attendance at the workshops, conferences, and technical webcasts will aid members in applying the results from this program. These results are delivered in the form of services, meeting notes, and web-based information with a focus on current industry information relating to steam turbine generator reliability, failure mechanisms, corrective action, and OEM guidance.

Several opportunities are offered to attend EPRI-sponsored events to share lessons learned with other utilities and stay abreast of technologies, including:

- EPRI T-G Technology Transfer Workshop and Steam Turbine Generator Workshop and Vendor Exposition
- Twice-yearly USA Turbine-Generator Users Group meetings and January workshop
- International Turbine-Generator Users Group meetings in Europe and Australia
- Technical webcasts offered to domestic and international members appropriate to their time zone schedules
### 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GO/GOP Forum (Formerly NERC Compliance Interest Group):</strong> EPRI’s GO/GOP Technical Focus Group represents the owners and operators of fossil, nuclear, and hydroelectric turbine generators for the purpose of collection and exchange of information on compliance with NERC standards. The group interfaces and collaborates on technical matters with other organizations, including the North American Generator Forum, North American Transmission Forum, and the generation subcommittees of the NERC regions. The group meets once a year and conducts regular conference calls.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Comprehensive On-Line Generator Monitoring Interest Group:</strong> The goals of this interest group are to learn from industry experiences how to integrate the standard instrumentation (e.g. temperature, pressure, vibration sensors) with the single purpose on-line monitors (e.g. flux probe, partial discharge, shaft voltage, end-winding monitors) and to learn about different techniques that have been already implemented by others. Examples are: Generator field resistance and temperature monitoring to detect collector brush problems, shaft voltage monitoring to confirm presence of shorted rotor winding turns, on-line detection of wet water-cooled stator winding. The group meets once a year during the meeting of the Fleet-wide Monitoring Interest Group (FWMIG).</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Two Turbine Generator User Group (TGUG) Meetings with Associated Winter Workshop:</strong> The 25th and 26th USA Turbine Generator User Group meetings will be held in January, 2011 and August 2011, respectively. The location for the January meeting will be Phoenix, Arizona, and the August meeting will be in Chattanooga, Tennessee, with an associated tour of the Alstom turbine-generator facility.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Technical Webcasts:</strong> Since 2008, Program 65 has conducted a series of four to six technical webcasts per year, each approximately two hours long, on a variety of turbine and generator topics selected by our members. Past webcasts include torsional vibration, water induction, and steam turbine performance. Due to positive feedback from members, P65 will continue this in 2012.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>13th EPRI Steam Turbine-Generator Workshop and Vendor Exhibition:</strong> This is a two-day workshop held in conjunction with the 2012 Summer TGUG meeting. This workshop will include parallel tracks, covering topics on steam turbine O&amp;M, generator O&amp;M, nondestructive evaluation, stress corrosion cracking, and corrosion fatigue. Presentations will be made by utility representatives, consultants, OEMs, vendors, and EPRI staff.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Steam Turbine-Generator Failures Yearly Report:</strong> Each year, EPRI solicits industry data on turbine and generator failures. This project captures failure data, including event descriptions, root-cause analysis, and lessons learned to be shared with the power generating industry.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>European TGUG Meeting:</strong> The 3rd Australian Turbine Generator User Group (TGUG) meeting and workshop will be held in April, 2012 in the Brisbane, Australia area. It will include a two-day workshop with concurrent turbine and generator workshop sessions, followed by a one-day TGUG meeting.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
</tbody>
</table>
Supplemental Projects

**Productivity Improvement Expert Review (PIER) (052986)**

**Background, Objectives, and New Learnings**

The improvement of fossil plant productivity is an essential element of a strategy to stay profitable in a competitive generation environment. As technology advances and new concepts and equipment are deployed in operating plants, a knowledge of what has worked—and its value—becomes essential to power plant operators. Staying abreast of these advances and selecting those that have value are the objectives of the participants in the collaborative, web-based, Productivity Improvement Expert Reviews (PIER) project.

**Project Approach and Summary**

The Productivity Improvement Expert Reviews (PIER) project—a broad collaborative of generating companies—pursues innovative, value-added, and critically assessed technologies that have been deployed in power plants worldwide. The scope of this work covers all major components of the power plant: boilers, turbines, generators, heat exchangers, and emissions control equipment; and maintains the focus of the EPRI Productivity Improvement Handbook for Fossil Steam Power Plants on well-proven case studies and clearly quantified benefits.

The collection and critical assessment of published information regarding creative innovations that have been carried out and successfully tested in operating plants are of critical value to companies operating in a competitive generation environment. Reviews of the selected innovations are published frequently, at approximately two-week intervals, on the project website. An expert in the specific field reviews each selected case study prior to publication. These comments and insights provide a solid basis for further application. In-house training courses are available, and the funding provides for updating of the course material.

**Benefits**

- Learn from and apply the lessons learned from other plant operators about maintenance and repair techniques and productivity improvement.

- Access regular bi-weekly updates on the project website.

**Locating Hydrogen Gas Leaks in Main Generator Using SF6 (071039)**

**Background, Objectives, and New Learnings**

Hydrogen that escapes from the generator housing is an explosive safety hazard. The operator first becomes aware of hydrogen leaks through hydrogen pressure drop or action of the automatic make-up line. In units that do not have automatic make-up, the hydrogen has to be replenished from hydrogen bottles connected to the make-up line. The leak rate is calculated, and unless there is massive leak (several thousands of cubic feet a day), operators usually choose to keep the generator operating.

Locating leaks in an operating machine by using the traditional "soap bubbles" method and portable leak detectors is dangerous, because the investigator must be near or on the generator. Leaks around the bushings cannot be investigated because of the presence of high voltage and current.

Leaks in generator housing have been successfully detected when SF6 gas was introduced as a tracer gas into the air or hydrogen inside the generator or stator winding. EPRI has developed a laser camera to detect SF6 gas leaks in substation equipment. But there now is concern about SF6 compatibility with generator internal materials (such as retaining rings [18Mn-5Cr, 18Mn-18Cr], Teflon® hoses, and electrical insulation), moisture, oil contamination, and decomposition of SF6 into toxic substances by an electrical arc or partial discharge.
Project Approach and Summary

The objective of this project is to provide scientific data for safe application of SF6 to detect hydrogen leaks online. The project consists of four tasks:

- Perform a literature search: Technical literature, including the EPRI reports, deals mostly with pure SF6. The literature search will focus on behavior of diluted SF6.
- Propose a test plan: The plan will be reviewed and approved by the project participants at a project review meeting.
- Procure generator sub-components and materials: Procure retaining rings (18Mn-5Cr, 18Mn-18Cr) material samples, Teflon® hoses, and samples of electrical insulation.
- Perform the test and report the results: A project review will be held during the testing to review preliminary results.

Benefits

Excessive hydrogen leaks in areas where the hydrogen can accumulate are a safety hazard. Locating leaks can be a time-consuming task. The unit can continue to run until a scheduled outage if the area of the leak can be safely vented. Eliminating the 24-hour air tightness test can save the plant $50,000 or more if the generator is on the outage critical pass.

NDE For Last Stage Rotor Turbine Blade Attachments (070922)

Background, Objectives, and New Learnings

Pinned finger joints are a common design of several turbine manufacturers for the last-stage blade attachments. In this design, blade roots are stacked in inverse contour of the rotor and then locked by pins. During operation, the areas around pin holes are under high stress and are subject to cracking.

Project Approach and Summary

This project will expand on prior evaluations of complementary metal oxide semiconductor (CMOS) technology as a direct digital radiographic detector for cracking. Earlier projects determined that a CMOS detector currently available is fully capable of detecting cracking in boiler waterwall tubes while in place, and through insulation and other building structures around the boiler.

This project will consist of assembling a system, including optimization of CMOS detector parameters for high-energy X-ray sources; acquisition of the detectors; acquisition of a portable linear accelerator device; and development of data display software to accurately display the geometry of the rotor blade attachments. Once the prototype system is assembled and laboratory verification completed, a field trial will be conducted to verify operational feasibility and user friendliness.

Benefits

Complete ultrasonic examination cannot be performed with the blades in place, due to multiple interfaces associated with the attachment design that prevent the transmission of ultrasound. Only the outer finger section could be examined with that technology. The cost of blade removal, NDE, and re-assembly can approach nearly $1M and can lead to damage in the rotor. Because cracking and subsequent failure could occur at any of the attachment fingers, there exists a need to examine the full attachment. High-energy radiography presents an opportunity to perform such an examination. The ability to use real-time digital radiography as the turbine is slowly rotating during the examination presents a means of detecting any cracking in less than one hour per stage.
LPRimLife Finger Attachment Module (070509)

Background, Objectives, and New Learnings

The EPRI LPRimLife software has been used for more than a decade to analyze cracks in low-pressure (LP) turbine rotors and provide a conservative estimate of runtime remaining before repair or replacement is necessary.

Although a number of other attachment types are already installed, finger root attachments still are outside of the scope of the software. The addition of modules to cover this design type would enhance the value of the software by improving risk-based decisions through increased accuracy of L-0 and L-1 blade failure analysis that could result in shorter outage durations through more targeted rotor cracking remediation strategies.

Project Approach and Summary

Using finite element analysis (FEA), stress profiles will be created of finger root attachments for LP turbine rotor sections under a combination of degradation conditions to be used as analysis models for the members. These profiles will be available to be loaded as modules in the next release of the EPRI LPRimLife software, allowing for analysis of a greater number of rotors.

Benefits

More than a decade of successful use of EPRI’s LPRimLife for analysis of LP turbine rotors puts the LPRimLife software in a unique position among fracture analysis tools. By adding modules to handle the analysis of finger root attachments, members will be able to perform more efficient analysis of those attachments.

Turbine Generator Users Group (069786)

Background, Objectives, and New Learnings

EPRI’s Turbine Generator Users Group (TGUG) was chartered in the United States in January 2000 to address an industry need for improved information exchange on fossil and nuclear steam turbine-generator issues, maintenance practices, and risk management. Since TGUG’s inception, membership has grown to include more than 70 power producers and seven steam turbine-generator manufacturers worldwide. The semiannual U.S. TGUG meetings are scheduled in conjunction with related Electric Power Research Center (EPRI) workshops and technical meetings to minimize travel costs for members. Meeting agendas are developed collaboratively by EPRI staff and the TGUG officers, who are elected from member organizations. The TGUG organization has now expanded to have groups in Australia, New Zealand, and Europe.

Project Approach and Summary

The objectives of the Steam Turbine/Generator Users Group are to:

- Acquire and exchange information on maintenance, inspection, performance upgrades/uprates, repair, testing, storage, and handling of all types of steam turbine, generators, and associated systems and sub-components.
- Discuss and exchange information on applicable codes and standards related to all types of steam turbines, generators, and associated systems and sub-components.
- Engage in activities that will improve the reliability and availability of all types of steam turbines, generators, and associated systems and sub-components. This can include establishing working groups to address specific issues.
- Provide a forum for discussion of operation and maintenance of all types of steam turbines, generators, and associated systems and sub-components, and serve as a technical information resource for the industry on this topic.
- Identify steam turbine, generator, and associated systems industry issues, and establish appropriate process for resolution — i.e., initiation of a Program 65 (Steam Turbine-Generator and Auxiliary Equipment) project, original equipment manufacture (OEM) resolution, and utilize non-OEM contractor.
• Provide a forum in which OEM’s, the Institute of Nuclear Power Operations (INPO), vendors, and utility personnel can interface and exchange ideas on topics concerning all types of steam turbines, generators, and associated systems and sub-components

Benefits

• Acquire and exchange information on maintenance, inspection, performance upgrades/uprates, repair, testing, storage, and handling of all types of steam turbine, generators, and associated systems and sub-components.
• Discuss and exchange information on applicable codes and standards related to all types of steam turbines, generators, and associated systems and sub-components.
• Engage in such activities that will improve the reliability and availability of all types of steam turbines, generators, and associated systems and sub-components. This will include establishing working groups, as needed, to address specific issues.
• Provide a forum for discussion of operation and maintenance of all types of steam turbines, generators, and associated systems and sub-components and serve as a technical information resource for the industry on this topic.
• Identify steam turbine, generator, and associated systems industry issues, and establish appropriate process for resolution — i.e., resolve within user group, initiation of a Program 65 (Steam Turbine-Generator and Auxiliary Equipment) project, equipment OEM resolution, and utilize non-OEM contractor.

On-Line Monitoring of Generators and Large Motors Using Electromagnetic Signature Analysis (EMSA) Interest Group (063655)

Background, Objectives, and New Learnings

EPRI is seeking worldwide power generators interested in noninvasive, on-line monitoring of generators and medium voltage motors using electromagnetic signature analysis (EMSA, also known as EMI)

Project Approach and Summary

Electromagnetic Signature Analysis (EMSA) is used as a system-wide surveillance technique that can detect and identify, with a single test, electric insulation defects in a motor, generator and associated electrical systems. The objectives of the interest group are to apply EMSA to power plant equipment (motors, generators, breakers, iso-phase bus) and to integrate it into existing predictive maintenance programs. The group that started in 2006 meets annually at participants sites.

Benefits

Several conditions were identified on-line with EMSA and trended. In most cases, the trending allowed the repairs to be scheduled during outages. EMSA also verified the repairs were made properly. Documented benefit-to-cost ratio exceeds 10:1.

Arc Flash for Medium-Voltage Equipment (072114)

Background, Objectives, and New Learnings

EPRI has had a series of projects on distribution arc flash. One of the most consistent findings is that arc flash is equipment specific. Energies depend strongly on electrode configurations and enclosure geometries. One of the most surprising results was from tests on a medium-voltage pad-mounted switch that produced incident energies three times higher than predicted by IEEE 1584 models. This particular switch had a bus configuration that focused the arc and fireball out the front of the enclosure in the direction where a worker would be standing.
The main objective of this project is to test more equipment and use results to develop arc flash models for that equipment. We plan to share results with the IEEE 1584 Working Group to help it improve future versions of the IEEE Guide for Performing Arc Flash Hazard Calculations.

Project Approach and Summary
The main work will involve testing equipment at a high-current laboratory. Tests will be instrumented with calorimeters and high-speed cameras to allow us to capture more data on the physics behind arc flash events.

Benefits
This project should help utilities implement better arc flash programs. Results will help utilities to coordinate protective clothing, relaying, and work practices.

Testing will help to answer several questions on arc flash in gear:

- Do existing IEEE 1584 models accurately predict energy in real gear
- How much energy is blocked by the circuit breaker for a fault in the back of the switchgear
- How does the incident energy change with equipment size and bus spacings
- How does the incident energy vary with time

Transformer & Circuit Breaker – Fleet Management (072021)

Background, Objectives, and New Learnings
Because of the adverse demographic distributions common in many utilities, existing methods need improvement to provide effective management of the fleets of aging transformers and high-voltage circuit breakers. Operating substation transformers and high-voltage circuit breakers reliably and with a low risk of failure at or beyond typically assumed design lives is a subject of interest for many utilities. Consequently, developing and justifying a repair/refurbish/replace management strategy for such populations, and the rational basis for it, are increasingly important.

Fleet management requires the tools and methodologies to better assess equipment performance and risk and provide quantitative information to drive asset management decision processes. In addition, fleet management risk and performance assessment tools can be integrated into smart grid implementations, turning smart grid-generated equipment status data into information and providing timely equipment and system condition and risk exposure metrics to improve operating reliability and efficiency. For practical implementation, fleet management tools should be based on actual equipment condition and rely on readily available data. EPRI has developed a foundation for a suite of integrated risk and performance assessment tools for substation equipment and successfully demonstrated the concepts in the application of algorithms at a number of utilities. However, the tools and algorithms are not complete and will benefit from additional development and application experience.

The objective is a set of integrated substation equipment risk and performance assessment tools designed to provide the information required to better assess equipment performance and risk and provide the quantitative information needed for best-practice fleet management and efficient operation.

Project Approach and Summary
Building on an established framework, the objectives of this project are to address primary concerns, issues, and utility needs for managing aged substation transformer and high-voltage circuit breaker fleets by assessing data availability and quality and its potential for short- and longer-term application to fleet management, to formulate and assess applicability of innovative methodologies for fleet management applications, to further develop and apply the new methodologies to quantitative business case analyses for a range of specific host utility fleet management strategies, to populate and exercise models with utility data, and to carry out sensitivity analysis for business cases being considered.
Benefits

Project results will help asset managers and maintenance personnel deal with the problem of populations of aged transformers and circuit breakers by formulating innovative, risk-based analytical methodologies to address emergent issues, maintenance strategies, monitoring strategies, and longer-range investment strategies. Specific benefits include the following:

- Reduce overall maintenance costs, project capital cash flow, minimize unplanned expenses, and maximize the benefit and value of planned work
- Improve reliability and availability via reduced reliance on time-based maintenance by using asset health and condition analysis to determine maintenance actions
- Enable more effective use of existing infrastructure and data and efficient use of maintenance personnel to manage operational risk

Users Group for the Power Plant Parameter Derivation (PPPD) Software Tool (072030)

Background, Objectives, and New Learnings

For more than a decade, the U.S. Western Electricity Coordinating Council (WECC) has required that all generating stations be periodically tested for model validation. Similar model validation requirements are going to be put in place nationwide by NERC. After several years of R&D, EPRI has developed a Power Plant Parameter Derivation (PPPD) software tool. This tool has been used successfully to illustrate automated parameter fitting and model validation through two approaches: using staged test measurement data and using data recorded on-line from disturbance monitors (for example, digital fault recorders in the plant). This users group has the objective of being a forum for utilities that intend on using the tool to share learning and to better understand the tool’s application for meeting WECC and NERC requirements for generator model validation.

Project Approach and Summary

This project will focus on holding group webcasts and one annual face-to-face meeting. These forums will be an ideal setting for the following:

- To discuss enhancements and develop additional model requirements to be added to the tool
- To maintain the software and release future versions of the tool with new models (“bug fixes”)
- To share experience of various users with the tool

To provide further training sessions

Benefits

This tool has two key values:

- It provides an automated algorithm to assist the engineer in the model validation process, significantly reducing engineering time.
- It provides a way to use on-line recorded data for model revalidation on a routine basis, eliminating the need to take units off-line for staged model validation testing.

A detailed explanation of the project and benefits of the work completed can be found in the 2009 base fund R&D project report.

This project will provide a forum to help utilities with the application of PPPD through workshops, users group meetings, webcasts, and software support. It also provides a way to continue to enhance the tool by adding more models or features to it, as appropriate.
316(b) Fish Protection Compliance Strategies (072033)

Background, Objectives, and New Learnings

The electric power industry has a large fleet of existing plants that will be affected by the final Rule. EPA’s proposal will require all generation facilities withdrawing more than 2 million MGD, including those with closed-cycle cooling, to meet stringent impingement mortality reduction requirements. Once-through cooled units withdrawing more than 2 MGD are also subject to entrainment mortality reduction requirements, however, only those withdrawing more than 125 MGD actual intake flow are required to submit extensive information on entrainment mortality reduction technologies.

This decision analysis project will assist power companies in selecting cost-effective, technologically appropriate, scientifically logical, and environmentally protective approach for compliance with the impingement mortality reduction standards; in budgeting for initial information and study requirements; and in providing key technical information required within six months of the final Rule.

The proposed EPA Rule requires all electric generating facilities to reduce impingement mortality using one of two options: biological monitoring to verify impingement mortality does not exceed 12% annually and 31% monthly, or reduce the maximum through-screen design velocity so it does not exceed 0.5 fps. Additional requirements apply if 0.5 fps exists or is attained and there is potential for fish entrapment; for facilities withdrawing from oceans or tidal waters, there are additional requirements for shellfish protection. For the vast majority of facilities, the impingement reduction requirements will mean making significant modifications to the design and operation of the cooling water intake structure.

Facilities must submit key information within six months of the effective date of the final Rule, including an Impingement Mortality Reduction Plan (3.5 years allowed for final plan). Entrainment mortality reduction is determined on a case-by-case basis with a significantly longer period to submit information, with the exception of the entrainment mortality data collection plan. The flexibility provided in the Rule offers tremendous potential for the industry to optimize compliance for each site, with associated cost savings. But incorrect assumptions or decisions could also lead to significant cost penalties and/or technologies that fail to meet the prescriptive impingement mortality reduction requirements. Developing compliance option information and decision tools will support the selection of the most cost-effective solution(s) for each site.

Project Approach and Summary

This collaborative project, led by a team of EPRI and industry experts, proposes to support companies in selecting the most cost-effective means to meet the impingement mortality reduction requirements for each facility, estimate financial exposure, estimate technological exposure, budget for initial compliance requirements, and support development of initial submittal information. As a result of the nature of the specific requirements and the relatively short time allowed for option selection and information submittal, the project will focus primarily on the criteria that most affect impingement mortality reduction requirements. Specific new learning will occur based on the evaluation of site-specific locations. The project approach will involve use of site-specific information to create a decision tree analysis of potential outcomes, based on the best science and technological advancements found in the literature or in practice or recommended to the industrial community; on EPRI technical information; on site visits; and on a webcast on implications of the final Rule.

Risk Exposure – EPRI has developed extensive data on the costs of closed-cycle cooling retrofits and other entrainment reduction technologies as well as their potential benefits. Using the most appropriate impingement mortality reduction technologies and selection process may lead to significant economic risk exposure. Participating facilities will be provided with preliminary cost estimates for entrainment compliance for use in Form 10K reporting, strategic planning, or both.

Impingement Mortality Reduction Option Selection – Each facility will need to select an impingement mortality reduction compliance option using a decision tree, and a reasonable estimate of the cost of those options is critical to making a cost-effective selection. EPRI, using a combination of a site visit to acquire engineering design and hydraulic operating information and its experience in fish protection technology
research, will identify practical alternatives and their costs for participating facilities. During the site visit EPRI will meet with company and facility personnel to discuss preliminary findings and address questions on the proposed Rule.

**Information Submittal Support** – The proposed Rule at section 122.21(r)(7) requires submittal of performance studies based on existing information. EPRI will prepare a report documenting available performance study information that can be used to meet this requirement. EPRI will also provide facilities with budget estimates for information and study requirements for the first 3.5 years.

**Webcast** - EPRI will conduct a webcast in the late fall of 2012 after the final Rule is issued. The workshop will cover changes in the final Rule and technical issues raised as well as overall findings of the 2012 research.

**Benefits**

EPA will finalize its 316(b) rule for existing facilities by July 27, 2012. The proposed Rule provides a clear indication of potential requirements for compliance in the final Rule. EPRI research will help companies better manage impingement and entrainment issues, which have an additional public benefit of preserving fish populations. This work helps electric power companies and the public understand how plants might be causing adverse environmental impacts and allow for the most economic compliance options. This research assists companies in planning a cost-effective compliance strategy and timely submittal of documents within six months of the effective date of the final Rule. This work will

- aid companies in estimating financial compliance exposure,
- provide guidance on selection of the most cost-effective options for impingement mortality reduction compliance,
- provide assistance in budgeting for compliance, and
- provide performance study information.
Supplemental Projects

Productivity Improvement Expert Review (PIER) (052986)

Background, Objectives, and New Learnings
The improvement of fossil plant productivity is an essential element of a strategy to stay profitable in a competitive generation environment. As technology advances and new concepts and equipment are deployed in operating plants, a knowledge of what has worked—and its value—becomes essential to power plant operators. Staying abreast of these advances and selecting those that have value are the objectives of the participants in the collaborative, web-based, Productivity Improvement Expert Reviews (PIER) project.

Project Approach and Summary
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Access regular bi-weekly updates on the project website.
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Project Approach and Summary

The objective of this project is to provide scientific data for safe application of SF6 to detect hydrogen leaks on-line. The project consists of four tasks:

- Perform a literature search: Technical literature, including the EPRI reports, deals mostly with pure SF6. The literature search will focus on behavior of diluted SF6.
- Propose a test plan: The plan will be reviewed and approved by the project participants at a project review meeting.
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This project will consist of assembling a system, including optimization of CMOS detector parameters for high-energy X-ray sources; acquisition of the detectors; acquisition of a portable linear accelerator device; and development of data display software to accurately display the geometry of the rotor blade attachments. Once the prototype system is assembled and laboratory verification completed, a field trial will be conducted to verify operational feasibility and user friendliness.

Benefits

Complete ultrasonic examination cannot be performed with the blades in place, due to multiple interfaces associated with the attachment design that prevent the transmission of ultrasound. Only the outer finger section could be examined with that technology. The cost of blade removal, NDE, and re-assembly can approach nearly $1M and can lead to damage in the rotor. Because cracking and subsequent failure could occur at any of the attachment fingers, there exists a need to examine the full attachment. High-energy radiography presents an opportunity to perform such an examination. The ability to use real-time digital radiography as the turbine is slowly rotating during the examination presents a means of detecting any cracking in less than one hour per stage.
LPRimLife Finger Attachment Module (070509)

Background, Objectives, and New Learnings

The EPRI LPRimLife software has been used for more than a decade to analyze cracks in low-pressure (LP) turbine rotors and provide a conservative estimate of runtime remaining before repair or replacement is necessary.

Although a number of other attachment types are already installed: finger root attachments still are outside of the scope of the software. The addition of modules to cover this design type would enhance the value of the software by improving risk-based decisions through increased accuracy of L-0 and L-1 blade failure analysis that could result in shorter outage durations through more targeted rotor cracking remediation strategies.

Project Approach and Summary

Using finite element analysis (FEA), stress profiles will be created of finger root attachments for LP turbine rotor sections under a combination of degradation conditions to be used as analysis models for the members. These profiles will be available to be loaded as modules in the next release of the EPRI LPRimLife software, allowing for analysis of a greater number of rotors.

Benefits

More than a decade of successful use of EPRI’s LPRimLife for analysis of LP turbine rotors puts the LPRimLife software in a unique position among fracture analysis tools. By adding modules to handle the analysis of finger root attachments, members will able to perform more efficient analysis of those attachments.
Turbine Generator Users Group (069786)

Background, Objectives, and New Learnings
EPRI’s Turbine Generator Users Group (TGUG) was chartered in the United States in January 2000 to address an industry need for improved information exchange on fossil and nuclear steam turbine-generator issues, maintenance practices, and risk management. Since TGUG’s inception, membership has grown to include more than 70 power producers and seven steam turbine-generator manufacturers worldwide. The semiannual U.S. TGUG meetings are scheduled in conjunction with related Electric Power Research Center (EPRI) workshops and technical meetings to minimize travel costs for members. Meeting agendas are developed collaboratively by EPRI staff and the TGUG officers, who are elected from member organizations. The TGUG organization has now expanded to have groups in Australia, New Zealand, and Europe.

Project Approach and Summary
The objectives of the Steam Turbine/Generator Users Group are to:

- Acquire and exchange information on maintenance, inspection, performance upgrades/uprates, repair, testing, storage, and handling of all types of steam turbine, generators, and associated systems and sub-components.
- Discuss and exchange information on applicable codes and standards related to all types of steam turbines, generators, and associated systems and sub-components.
- Engage in activities that will improve the reliability and availability of all types of steam turbines, generators, and associated systems and sub-components. This can include establishing working groups to address specific issues.
- Provide a forum for discussion of operation and maintenance of all types of steam turbines, generators, and associated systems and sub-components, and serve as a technical information resource for the industry on this topic.
- Identify steam turbine, generator, and associated systems industry issues, and establish appropriate process for resolution — i.e., initiation of a Program 65 (Steam Turbine-Generator and Auxiliary Equipment) project, original equipment manufacture (OEM) resolution, and utilize non-OEM contractor.
- Provide a forum in which OEM’s, the Institute of Nuclear Power Operations (INPO), vendors, and utility personnel can interface and exchange ideas on topics concerning all types of steam turbines, generators, and associated systems and sub-components.

Benefits

- Acquire and exchange information on maintenance, inspection, performance upgrades/uprates, repair, testing, storage, and handling of all types of steam turbine, generators, and associated systems and sub-components.
- Discuss and exchange information on applicable codes and standards related to all types of steam turbines, generators, and associated systems and sub-components.
- Engage in such activities that will improve the reliability and availability of all types of steam turbines, generators, and associated systems and sub-components. This will include establishing working groups, as needed, to address specific issues.
- Provide a forum for discussion of operation and maintenance of all types of steam turbines, generators, and associated systems and sub-components and serve as a technical information resource for the industry on this topic.
- Identify steam turbine, generator, and associated systems industry issues, and establish appropriate process for resolution — i.e., resolve within user group, initiation of a Program 65 (Steam Turbine-Generator and Auxiliary Equipment) project, equipment OEM resolution, and utilize non-OEM contractor.
- Provide a platform for OEM’s, INPO, vendors, and utility personnel to interface and exchange ideas on topics concerning all types of steam turbines, generators, and associated systems and sub-components.
On-Line Monitoring of Generators and Large Motors Using Electromagnetic Signature Analysis (EMSA) Interest Group (063655)

Background, Objectives, and New Learnings

EPRI is seeking worldwide power generators interested in noninvasive, on-line monitoring of generators and medium voltage motors using electromagnetic signature analysis (EMSA, also known as EMI)

Project Approach and Summary

Electromagnetic Signature Analysis (EMSA) is used as a system-wide surveillance technique that can detect and identify, with a single test, electric insulation defects in a motor, generator and associated electrical systems. The objectives of the interest group are to apply EMSA to power plant equipment (motors, generators, breakers, iso-phase bus) and to integrate it into existing predictive maintenance programs. The group that started in 2006 meets annually at participants sites.

Benefits

Several conditions were identified on-line with EMSA and trended. In most cases, the trending allowed the repairs to be scheduled during outages. EMSA also verified the repairs were made properly. Documented benefit-to cost ratio exceeds 10:1.
Arc Flash for Medium-Voltage Equipment (072114)

Background, Objectives, and New Learnings

EPRI has had a series of projects on distribution arc flash. One of the most consistent findings is that arc flash is equipment specific. Energies depend strongly on electrode configurations and enclosure geometries. One of the most surprising results was from tests on a medium-voltage pad-mounted switch that produced incident energies three times higher than predicted by IEEE 1584 models. This particular switch had a bus configuration that focused the arc and fireball out the front of the enclosure in the direction where a worker would be standing.

The main objective of this project is to test more equipment and use results to develop arc flash models for that equipment. We plan to share results with the IEEE 1584 Working Group to help it improve future versions of the IEEE Guide for Performing Arc Flash Hazard Calculations.

Project Approach and Summary

The main work will involve testing equipment at a high-current laboratory. Tests will be instrumented with calorimeters and high-speed cameras to allow us to capture more data on the physics behind arc flash events.

Benefits

This project should help utilities implement better arc flash programs. Results will help utilities to coordinate protective clothing, relaying, and work practices.

Testing will help to answer several questions on arc flash in gear:

- Do existing IEEE 1584 models accurately predict energy in real gear
- How much energy is blocked by the circuit breaker for a fault in the back of the switchgear
- How does the incident energy change with equipment size and bus spacings
- How does the incident energy vary with time
Transformer & Circuit Breaker – Fleet Management (072021)

Background, Objectives, and New Learnings

Because of the adverse demographic distributions common in many utilities, existing methods need improvement to provide effective management of the fleets of aging transformers and high-voltage circuit breakers. Operating substation transformers and high-voltage circuit breakers reliably and with a low risk of failure at or beyond typically assumed design lives is a subject of interest for many utilities. Consequently, developing and justifying a repair/refurbish/replace management strategy for such populations, and the rational basis for it, are increasingly important.

Fleet management requires the tools and methodologies to better assess equipment performance and risk and provide quantitative information to drive asset management decision processes. In addition, fleet management risk and performance assessment tools can be integrated into smart grid implementations, turning smart grid-generated equipment status data into information and providing timely equipment and system condition and risk exposure metrics to improve operating reliability and efficiency. For practical implementation, fleet management tools should be based on actual equipment condition and rely on readily available data. EPRI has developed a foundation for a suite of integrated risk and performance assessment tools for substation equipment and successfully demonstrated the concepts in the application of algorithms at a number of utilities. However, the tools and algorithms are not complete and will benefit from additional development and application experience.

The objective is a set of integrated substation equipment risk and performance assessment tools designed to provide the information required to better assess equipment performance and risk and provide the quantitative information needed for best-practice fleet management and efficient operation.

Project Approach and Summary

Building on an established framework, the objectives of this project are to address primary concerns, issues, and utility needs for managing aged substation transformer and high-voltage circuit breaker fleets by assessing data availability and quality and its potential for short- and longer-term application to fleet management, to formulate and assess applicability of innovative methodologies for fleet management applications, to further develop and apply the new methodologies to quantitative business case analyses for a range of specific host utility fleet management strategies, to populate and exercise models with utility data, and to carry out sensitivity analysis for business cases being considered.

Benefits

Project results will help asset managers and maintenance personnel deal with the problem of populations of aged transformers and circuit breakers by formulating innovative, risk-based analytical methodologies to address emergent issues, maintenance strategies, monitoring strategies, and longer-range investment strategies. Specific benefits include the following:

- Reduce overall maintenance costs, project capital cash flow, minimize unplanned expenses, and maximize the benefit and value of planned work
- Improve reliability and availability via reduced reliance on time-based maintenance by using asset health and condition analysis to determine maintenance actions
- Enable more effective use of existing infrastructure and data and efficient use of maintenance personnel to manage operational risk
Users Group for the Power Plant Parameter Derivation (PPPD) Software Tool (072030)

Background, Objectives, and New Learnings
For more than a decade, the U.S. Western Electricity Coordinating Council (WECC) has required that all generating stations be periodically tested for model validation. Similar model validation requirements are going to be put in place nationwide by NERC. After several years of R&D, EPRI has developed a Power Plant Parameter Derivation (PPPD) software tool. This tool has been used successfully to illustrate automated parameter fitting and model validation through two approaches: using staged test measurement data and using data recorded on-line from disturbance monitors (for example, digital fault recorders in the plant). This users group has the objective of being a forum for utilities that intend on using the tool to share learning and to better understand the tool’s application for meeting WECC and NERC requirements for generator model validation.

Project Approach and Summary
This project will focus on holding group webcasts and one annual face-to-face meeting. These forums will be an ideal setting for the following:

- To discuss enhancements and develop additional model requirements to be added to the tool
- To maintain the software and release future versions of the tool with new models (“bug fixes”)
- To share experience of various users with the tool

To provide further training sessions

Benefits
This tool has two key values:

- It provides an automated algorithm to assist the engineer in the model validation process, significantly reducing engineering time.
- It provides a way to use on-line recorded data for model revalidation on a routine basis, eliminating the need to take units off-line for staged model validation testing.

A detailed explanation of the project and benefits of the work completed can be found in the 2009 base fund R&D project report.

This project will provide a forum to help utilities with the application of PPPD through workshops, users group meetings, webcasts, and software support. It also provides a way to continue to enhance the tool by adding more models or features to it, as appropriate.
316(b) Fish Protection Compliance Strategies (072033)

Background, Objectives, and New Learnings

The electric power industry has a large fleet of existing plants that will be affected by the final Rule. EPA’s proposal will require all generation facilities withdrawing more than 2 million MGD, including those with closed-cycle cooling, to meet stringent impingement mortality reduction requirements. Once-through cooled units withdrawing more than 2 MGD are also subject to entrainment mortality reduction requirements, however, only those withdrawing more than 125 MGD actual intake flow are required to submit extensive information on entrainment mortality reduction technologies.

This decision analysis project will assist power companies in selecting cost-effective, technologically appropriate, scientifically logical, and environmentally protective approach for compliance with the impingement mortality reduction standards; in budgeting for initial information and study requirements; and in providing key technical information required within six months of the final Rule.

The proposed EPA Rule requires all electric generating facilities to reduce impingement mortality using one of two options: biological monitoring to verify impingement mortality does not exceed 12% annually and 31% monthly, or reduce the maximum through-screen design velocity so it does not exceed 0.5 fps. Additional requirements apply if 0.5 fps exists or is attained and there is potential for fish entrapment; for facilities withdrawing from oceans or tidal waters, there are additional requirements for shellfish protection. For the vast majority of facilities, the impingement reduction requirements will mean making significant modifications to the design and operation of the cooling water intake structure.

Facilities must submit key information within six months of the effective date of the final Rule, including an Impingement Mortality Reduction Plan (3.5 years allowed for final plan). Entrainment mortality reduction is determined on a case-by-case basis with a significantly longer period to submit information, with the exception of the entrainment mortality data collection plan. The flexibility provided in the Rule offers tremendous potential for the industry to optimize compliance for each site, with associated cost savings. But incorrect assumptions or decisions could also lead to significant cost penalties and/or technologies that fail to meet the prescriptive impingement mortality reduction requirements. Developing compliance option information and decision tools will support the selection of the most cost-effective solution(s) for each site.

Project Approach and Summary

This collaborative project, led by a team of EPRI and industry experts, proposes to support companies in selecting the most cost-effective means to meet the impingement mortality reduction requirements for each facility, estimate financial exposure, estimate technological exposure, budget for initial compliance requirements, and support development of initial submittal information. As a result of the nature of the specific requirements and the relatively short time allowed for option selection and information submittal, the project will focus primarily on the criteria that most affect impingement mortality reduction requirements. Specific new learning will occur based on the evaluation of site-specific locations. The project approach will involve use of site-specific information to create a decision tree analysis of potential outcomes, based on the best science and technological advancements found in the literature or in practice or recommended to the industrial community; on EPRI technical information; on site visits; and on a webcast on implications of the final Rule.

Risk Exposure – EPRI has developed extensive data on the costs of closed-cycle cooling retrofits and other entrainment reduction technologies as well as their potential benefits. Using the most appropriate impingement mortality reduction technologies and selection process may lead to significant economic risk exposure. Participating facilities will be provided with preliminary cost estimates for entrainment compliance for use in Form 10K reporting, strategic planning, or both.

Impingement Mortality Reduction Option Selection – Each facility will need to select an impingement mortality reduction compliance option using a decision tree, and a reasonable estimate of the cost of those options is critical to making a cost-effective selection. EPRI, using a combination of a site visit to acquire
engineering design and hydraulic operating information and its experience in fish protection technology research, will identify practical alternatives and their costs for participating facilities. During the site visit EPRI will meet with company and facility personnel to discuss preliminary findings and address questions on the proposed Rule.

Information Submittal Support – The proposed Rule at section 122.21(r)(7) requires submittal of performance studies based on existing information. EPRI will prepare a report documenting available performance study information that can be used to meet this requirement. EPRI will also provide facilities with budget estimates for information and study requirements for the first 3.5 years.

Webcast - EPRI will conduct a webcast in the late fall of 2012 after the final Rule is issued. The workshop will cover changes in the final Rule and technical issues raised as well as overall findings of the 2012 research.

Benefits

EPA will finalize its 316(b) rule for existing facilities by July 27, 2012. The proposed Rule provides a clear indication of potential requirements for compliance in the final Rule. EPRI research will help companies better manage impingement and entrainment issues, which have an additional public benefit of preserving fish populations. This work helps electric power companies and the public understand how plants might be causing adverse environmental impacts and allow for the most economic compliance options. This research assists companies in planning a cost-effective compliance strategy and timely submittal of documents within six months of the effective date of the final Rule. This work will

- aid companies in estimating financial compliance exposure,
- provide guidance on selection of the most cost-effective options for impingement mortality reduction compliance,
- provide assistance in budgeting for compliance, and
- provide performance study information.
Fossil Materials and Repair - Program 87

Program Overview

Program Description
Today's fossil power plants increasingly are adopting market-driven operating strategies such as cycling, pushing for maximum output during peak price periods, and frequent fuel switching to take advantage of spot market opportunities. These practices can accelerate material damage in major power block components. New materials are being introduced for replacement of components in aging plants and in the building of higher efficiency power plants. Improved knowledge of materials behavior in such environments allows for accurate prediction of remaining life, proper selection of repair strategies, and optimized material selection, fabrication, and repair.

To address these needs, the Electric Power Research Institute’s (EPRI’s) Fossil Materials and Repair program (Program 87) provides the integrated materials selection guidance, corrosion mitigation methods, and repair and welding technologies needed to improve equipment performance, reliability, and profitability.

Research Value
Safety and availability loss due to failures are two key issues driving R&D on major fossil power plant components, especially in older plants. Improved efficiency and reliability are two reasons for the selection of new materials for retrofit and new-build projects. EPRI’s Materials and Chemistry programs provide data on critical material degradation mechanisms, conduct materials and chemistry-related R&D for advanced generation technologies, and quantify the benefits of chemistry improvements. The programs help utilities balance the risks and costs of the largest, most costly equipment, and focus on using new technologies to create solutions. Members of the Fossil Materials and Repair program can use the R&D to:

- Increase availability through better understanding of plant materials;
- Eliminate repeat failures, minimize equipment damage, and reduce outage frequency and duration by using improved knowledge of damage mechanisms and life assessment methods;
- Reduce failures from high- and low-temperature corrosion;
- Obtain in-depth knowledge of advanced ferritic and austenitic alloys and processes used to fabricate and join these alloys;
- Use new and advanced repair technologies; and
- Maximize component life through improved materials selection guidance and procurement specifications.

Approach
Through a continuum of materials and repair guidelines, handbooks, technical projects, and conferences/workshops, the program helps manage and reduce the operating risks associated with material degradation and failure. Projects develop resources to estimate remaining life, assess and conduct state-of-the-art repairs, decide on replacement materials, and address costly corrosion and erosion problems faced in real-world business settings.

- Research into availability increases through improved materials performance focuses on all aspects of materials used in power production, including degradation, failure analysis, selection, component life assessment, and advancements in materials technologies. Key areas of research include materials guidelines, failure analysis guidelines, materials selection and advancements, new tools for evaluating in-service degradation of materials, and life prediction.
- Developments and repair solutions in fossil repair applications are provided to members via demonstrations, procedures, reports, conferences, and workshops. Deliverables are targeted to provide applications technologies to extend component life, reduce repair costs, improve materials performance, and reduce downtime for repair activities.
• R&D of reliability of materials in corrosive, abrasive, and high-temperature operation is aimed at reducing corrosion in power plant piping, heat exchangers, boiler tubing, and other components — which costs power companies millions of dollars each year — through improved understanding of corrosion mechanisms, innovative coatings assessments, and the development of models to predict and control corrosion phenomena.

Accomplishments

EPRI’s Fossil Materials and Repair program is a proactive industry leader in all aspects of plant materials performance, repair and welding technology development, and corrosion mitigation.

• Provided industry leadership in addressing fabrication, installation, welding, and degradation of creep-strength-enhanced ferritic steels and advanced austenitic stainless steels
• Developed comprehensive International Steam Boiler and Steam Turbine Metallurgical Guidelines
• Provided guidance on behavior and remaining life of austenitic stainless steel materials used for superheater and reheater tubing applications
• Developed welding guidelines for boiler applications and advanced ferritic and austenitic alloys
• Published a series of metallurgical handbooks (Grade 11, Grade 22, X20, carbon steels, and stainless steels)
• Developed new models for assessing oxide growth and exfoliation
• Provided innovative solutions and new welding consumables for dissimilar metal weld damage repair and advanced steels

Current Year Activities

The program R&D for 2012 will focus on key member issues, including the application of small specimen testing for qualitative and quantitative life assessments; application of knowledge on creep-fatigue damage; novel tools to improve the application of materials knowledge in the use of creep strength enhanced ferritic steels; improving failure analysis; and improved understanding of weldment cracking phenomenon in new boiler steels, oxidation of superheaters/reheaters, erosion issues in steam turbine components, and corrosion in environmental control equipment. Key specific efforts are expected to include:

• Material database for small specimen remaining life assessments
• Improved Grade 91 handbook
• Stress corrosion cracking and reheat cracking in T23/24 alloy welds
• Application of nanocoatings
• Steamside exfoliation model deployment
• Survey of corrosion and erosion issues in flue gas desulfurization system components

Estimated 2012 Program Funding

2.75M

Program Manager

John Shingledecker, 704-595-2619, jshingledecker@epri.com
## Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P87.001</td>
<td>Availability Increases Through Improved Materials Performance</td>
<td>This project performs research on all aspects of plant material performance, including damage mechanisms, metallurgical phenomenon, failure analysis, material selection, and component life assessment.</td>
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<tr>
<td>P87.002</td>
<td>Fossil Repair Applications and Welding Technology</td>
<td>This project provides members new repair technologies that are critical for maintaining the plant, addressing emergency failures, reducing outage times, and reducing the risk of future damage. Research addresses these needs through new innovative repair tools, new welding consumables, fabrication and installation guidance, productivity improvements in welding, and the performance of welded structures.</td>
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<tr>
<td>P87.003</td>
<td>Reliability of Materials In Corrosive, Abrasive, and High-Temperature Operation</td>
<td>This project performs research to understand the often complex corrosion and erosion issues related to plant materials. Solutions in the form of guidelines, technical reports, and coating technology are provided to program members.</td>
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### P87.001 Availability Increases Through Improved Materials Performance (058205)

#### Key Research Question

Today’s fossil power plants increasingly adopt market-driven operating strategies, such as cycling, pushing for maximum output during peak price periods, and frequent fuel switching to take advantage of spot market opportunities. These new operating modes can accelerate material damage in virtually all major power plant components, including pressure parts and rotating components. Proper selection of materials and the right operating strategy can eliminate damage while increasing plant availability and reducing repair costs. To accomplish this goal, improved understanding of damage mechanisms and material degradation is needed. The construction of new plants, mainly supercritical pulverized coal power plants and heat recovery steam generators (HRSG) in combined cycle plants, is using new materials for which specification guidance and data on performance are required.

#### Approach

This project focuses on all aspects of materials used in power production, including materials degradation, failure analysis, material selection, component life assessment, and advances in materials technologies. Developments in this area will be integrated with repair applications developed in Project 87.002 and corrosion and oxidation damage mechanisms evaluation in Project 87.003. Key areas of research will include materials guidelines, improved understanding of failure mechanisms, failure analysis guidelines, materials selection and advancements, and material-specific life prediction methodologies and data. When appropriate, joint activities with Programs 63, 65, and 88 are included to improve component life.

#### Impact

- Apply comprehensive metallurgical guidelines for both metallurgical property information and the tools to predict component life
- Help members evaluate advanced materials entering the market and the components fabricated from them and to select optimum materials for long-term operation
- Provide industry with tools and databases for small specimen testing to improve life assessment and understanding of in-plant material degradation
- Work with industry leaders in addressing creep-strength-enhanced ferritic steels (Grades 91, 92, 122, 23, and 24) and advanced austenitic alloys (347HFG, Super 304H, and HR3C.)
- Participate in the international development of guidelines and improved methodologies for assessing creep-fatigue damage in components, the result of unit cycling and deployment of a host of new alloys

How to Apply Results

Members can use the research information in this project to select optimum materials for a variety of components, ranging from piping, tubing, and headers to steam turbines and discs; gain the technical basis for improving internal material procurement specifications to ensure long-term material reliability; consistently apply improved remaining-life techniques to assess component life; address advanced ferritic and austenitic alloy issues; better understand the factors that can influence component damage and remaining life; and improve the methods used to conduct failure investigations.

2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tr>
<td><strong>New &amp; Updated Grade 91 Handbook</strong>: EPRI completed a four-year effort, combined with information from more than 40 members, covering all aspects of initial material integrity and damage development in Grade 91 components. The project also produced a practical life management strategy. Based on the recently completed research and material guidance, a new &quot;pocket-sized&quot; handbook will be produced to distill this information into a practical tool that power plant engineers can use to optimize Grade 91 component life. In addition to a hard copy book, the handbook is intended to be interactive and available as an easy-to-use electronic document for new smart phone applications.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Expansion of HRSG Materials Selection Guide</strong>: With the anticipated increased need for gas turbine combined-cycle plants, the construction of new heat recovery steam generators (HRSG) with improved performance is expected. In 2011, EPRI completed a detailed materials selection guide for HRSG high-pressure tubing components, covering a range of potential operating conditions and materials. A rigorous analytical approach was used to select optimum materials. In 2012, this work will be expanded to cover additional critical components including nonpressure parts such as duct burners.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Expanded Material Database for Small-Specimen Testing</strong>: In 2010 and 2011, EPRI program 87 developed the test equipment, baseline data, and an approach to improve small punch testing (SPT) for qualitative creep life assessment of boiler piping, used for improved life assessments of high-energy piping systems in aging plants. In 2012, this database will be expanded to include Grade 91 and 22, and work will begin to provide more quantitative assessment of data. An EPRI-led International SPT Experts Group will elaborate and harmonize testing and analyses of SPT data, which will form the basis for the development for correlation of SPT data with standard tensile and creep data for materials P22 and P91. This correlation will serve for condition assessment of components in service.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Failure Analysis Workshop</strong>: Power plant engineers, while technically competent, have limited background and knowledge of the collection, documentation, and preservation of both failed and unfailed parts, which may be critical to fully establishing root cause and prevent future failures. EPRI P87 has produced a three-volume failure analysis guideline to aid plant engineers. This workshop/training course will educate participants on the use of this guideline and other relevant P87 resources to improve participants' abilities to conduct a proper failure investigation. Multiple examples of good and poor practices during field failures will be used for this approach.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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**Product Title & Description**

**Implementation of Creep-Fatigue Databases to Components**: EPRI has led an international effort to produce a state-of-knowledge on creep-fatigue damage interaction, establish creep-fatigue testing standards, and develop material databases for life assessment. In 2012, EPRI will use these tools to identify operation modes and components that may be subjected to creep-fatigue damage. A creep-fatigue failure assessment method will be developed for materials subjected to cyclic loading at high temperature, based on a creep-fatigue failure assessment diagram (C-F FAD).

**Advanced Stainless Steel Pocket Handbook: 347HFG, Super 304H, HR3C**: EPRI has completed a state-of-knowledge report on the experience and behavior of a wide range of advanced austenitic stainless steels. A welding guideline also has been produced. The current worldwide application of this class of alloy in boiler tubes in modern supercritical and ultra-supercritical plants largely has been relegated to three main alloys: 347HFG (Fine-grained 347H), Super 304H, and HR3C (310HCrN). Using the available data, a convenient reference guide in the form of a pocket handbook (in the manner of the other EPRI P87 pocket handbooks) will be produced. The guide will be an easy-to-read quick reference for plant engineers with these alloys in their power plants.

**The Effect of Chemistry on Strain-Induced Precipitation Hardening of Stainless Steels**: Failures in cold-formed stainless steels due to strain-induced precipitation hardening (SIPH) have been observed over a number of years, and practical guidance for heat-treatment now exists. However, the role of alloy chemistry in the manifestation of the damage mechanism, especially trace alloying elements, niobium, and boron (within specifications and between alloys), remains unclear. This project aims to evaluate a series of austenitic stainless steels for the propensity for SIPH failures, with particular emphasis on the role of chemical composition of the base metal.

**Future Year Products**

**Product Title & Description**

**7th International Conference on Advances in Materials Technology for Fossil Power Plants**

**Quantitative Life-Assessment of Grade 22 Piping Using Small Punch Testing**

**P87.002 Fossil Repair Applications and Welding Technology (058206)**

**Key Research Question**

Reliable repair technologies are a key part of any organization’s run-repair-replacement decisions and are invaluable to power plant owners in maintaining the plant and addressing emergency failures. Repair of damage mechanisms investigated in 87.001 and corrosion evaluations from 87.003 will be key to this project. It incorporates two key topics: fossil plant repair applications (immediate repair needs) and advanced repair and welding technologies (focused on development of longer-reaching repair technologies, including improved welding consumables and improved understanding of weld performance).
Approach
Developments and repair solutions will be provided to members via demonstrations, procedures, reports, conferences, new products, and workshops. Deliverables include applications technologies to extend component life, reduce repair costs, improve materials performance, and reduce downtime for repair activities. Participants in this project gain direct access to EPRI's welding, materials, and power plant repair experts, as well as the collaborative expertise of fellow program participants.

Impact
- Improve practices, equipment, and methodologies to reduce the cost and time involved in repairing and replacing superheat and reheat tubing
- Provide innovative solutions for grade 91 welding and repair
- Ensure quality new plant and component performance by using welding, fabrication, and installation guidance when working with OEMs, vendors, and architectural engineering firms
- Apply guidelines for selecting weld metal and processes for the appropriate application
- Disseminate best practices

How to Apply Results
Members will have access to research results on advanced repair technology through guidelines and reports, such as the Fabrication and Installation Guidelines, which can be used to specify and follow fabrication practices used by vendors and OEMs. Members are encouraged to attend the conferences on welding and repair to ensure effective technology transfer. These conferences are supplemented by workshops and technical support services as required. Members will be able to use the adaptation of existing repair technology in new applications and development of repair technologies. Newly available consumable products, such as P87 filler metal, will be made available to improve welded component performance.

2012 Products

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<tbody>
<tr>
<td><strong>Welding and Repair Technology for Power Plants</strong>: An international conference, jointly sponsored by EPRI's Nuclear Welding and Repair Technology Center (WRTC) and EPRI P87 (Fossil Materials and Repair), to provide a forum for sharing recent advancements in manufacturing, fabrication, welding, installation, and repair of nuclear and fossil power plant components. The program is designed around technical exchange through presentations covering welding and repair research and experience, invited keynote speakers, a vendor fair, and ample opportunities for informal discussions with plant owners, power plant engineers, research scientists, welding and fabrication vendors, and original equipment manufacturers (OEMs).</td>
<td>07/01/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>New Interactive Grade 91 Welding Guideline</strong>: Most of the early failures and fabrication issues with the implementation of Grade 91 steel (P91, T91, F91) have been due to improper welding and post-weld heat-treatment (PWHT) of components in the field. Field engineers, welding engineers, and power plant staffs need tools that can be used to educate welders and quality assurance staff working in the field and on the construction site who have little to no knowledge of the complex metallurgy of these alloys. A small guide is envisioned, to provide a tool for quickly educating these staff members on proper handling, welding, and PWHT of Grade 91. The use of smart phone technology to accomplish this goal will be explored. The document will reference the much larger body of research already completed within EPRI programs and projects on Grade 91.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>
**Product Title & Description**  | **Planned Completion Date**  | **Product Type**
--- | --- | ---
**Repair Without PWHT for Thin-Section CSEF Steels:** With increased pressure to reduce plant maintenance time during peak loads or market opportunities, short-term repairs can have significant economic benefit. However, the increasing use of creep strength enhanced ferritic (CSEF) steels such as T91, T92, T23, and T24 in thin-section tubular applications necessitates longer repair times due to the need for post-weld heat-treatment (PWHT). In 2011, EPRI P87 conducted a scoping study on the applicability of temperbead repair techniques (welding with PWHT) on grade 91. Based on these initial tests, additional work to develop and optimized the procedures will be conducted for a range of applicable materials. | 12/31/12  | Technical Update

**Improved Understanding of SCC in CSEF steels:** Stress corrosion cracking (SCC) has been reported in creep-strength-enhanced (CSEF) steels, including Grade 91 and 23, during fabrication or after welding when post-weld heat-treatment (PWHT) is not performed properly and the material is exposed to a moist environment. The current guidance given for humidity, storage time, and material hardness is "rule-of-thumb," and needs to be revisited. Materials such as T23 and T24 are thought to be immune from this type of damage, but experience suggests otherwise. Limits for material hardness, time in environment, and residual stress have not been examined and compared for this class of alloy. The limits may be different, depending on alloy composition and other factors. This work will conduct fundamental studies on SCC in moist environments for these alloys to give scientifically based guidance on material handling as a function of material. | 12/31/12  | Technical Update

**Stress-Relief Cracking in Chromium Molybdenum Steels 23 and 24:** Steels T23 and T24 are increasingly used in boiler waterwall and heat recovery steam generators (HRSGs). HRSG construction is expected to expand to meet short-term demands for power in gas turbine combined-cycle plants due to low cost of natural gas. Welding of these alloys is significantly more challenging than traditional T22. This work will investigate the susceptibility of these alloys to stress-relief cracking and reheat cracking. Using this information, the project will develop improved weld bead placement, joint geometry, and heat-treatment recommendations for both new construction and component repair. | 12/31/12  | Technical Update

**Future Year Products**
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| **Product Title & Description**  | **Planned Completion Date**  | **Product Type**
--- | --- | ---
**Welding and Repair Technology for Power Plants**  | 07/01/14  | Technical Resource

**Weld Metal & Process Selection for Joints Operating in High-Temperature Service**  | 12/31/14  | Technical Update

**Improved Understanding of SCC in CSEF Steels**  | 12/31/14  | Technical Report
P87.003 Reliability of Materials In Corrosive, Abrasive, and High-Temperature Operation (058207)

Key Research Question
Corrosion in power plant piping, heat exchangers, boiler tubing, and other components costs power companies millions of dollars each year. At high temperatures, oxides growing in steam circuits control many of the failure and damage mechanisms around the plant, including remaining life, solid particle erosion, and short-term overheating. Hot corrosion attack and wastage due to erosion reduce tube life and require coatings, weld overlay, or alternate materials. Additionally, fossil power plants experience a multitude of low-temperature corrosion problems in a variety of plant systems, including raw water and pretreatment systems, cooling water, service water and fire protection systems, condensers, cooling towers, auxiliary heat exchangers, low-pressure feedwater heaters and piping, deaerators, steam turbines, electric generators, air heaters and ducts, flue gas desulfurization systems, and flue gas ducts and stack. Corrosion problems with high cost impact on the fossil power industry will receive highest priority.

Approach
This project addresses corrosion and abrasive damage at both low and high temperatures through the development of a fundamental understanding of these damage mechanisms affecting power plant materials and components. Various coatings, including nanostructured coatings, will be investigated for mitigation of both corrosion and erosion in various components. Modeling of the corrosion process and methodologies to control key industry issues such as exfoliation of stainless steel tubing will be undertaken.

Impact
- Temperature effects as a result of an oxide scale buildup can have an adverse impact on remaining life, and how the oxide exfoliates can determine if tube pluggage and resulting short-term overheat or turbine solid particle erosion (SPE) damage is a concern. This project will investigate new materials as they are developed and installed in power plants to understand the oxidation rate, oxide morphology, and eventual exfoliation of the oxide.
- Develop improved understanding of high-temperature erosion and corrosion in hard-facing alloys
- Improve many aspects of power plant equipment condition, including oxidation, corrosion, and erosion resistance, with developments in nanostructured coatings
- Minimize damage and address all metallurgical aspects of low-temperature corrosion

How to Apply Results
Results delivered through guidelines, reports, and workshops can give members a fundamental understanding of damage mechanisms affecting power plant components. Knowing how oxides exfoliate can assist in determining if tube plugging is likely and in understanding solid particle erosion of turbine blade diaphragms. The guidelines can be integrated in members’ processes and procedures to improve operations and reduce damage caused by high-temperature operations.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
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<th>Product Type</th>
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<tr>
<td>Nanostructured Coatings for Improved Erosion Resistance of Steam Turbine Valve Stems: EPRI has developed tough, adherent, erosion-resistant nanocoatings and completed a research project for coating typical steam turbine valve stem materials. Field trials were initiated in 2011. Additional field trials will be conducted in 2012 when required, and will evaluate materials after removal from the field. This project will document progress made and performance of the field trials.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</tbody>
</table>
### Product Title & Description

<table>
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<tr>
<th>Review of FGD Materials Performance: A new generation of flue gas desulfurization (FGD) systems has been constructed for improved sulfur removal. The materials of construction for various components vary greatly depending on utility, manufacturer, and operating needs. Additionally, older units continue to run. In addition to work being conducted on corrosion in the metallic tanks and piping of these new units constructed with metallic alloys (often duplex stainless steel), there are many other materials and components with performances not widely documented. This project will use surveys and site visits to identify the materials of construction for the major components in these systems; document the performance of the alloys, coatings, refractories, composites, and plastics; and compare the industry experiences. Participants will gain firsthand knowledge of how components are performing, helping them make informed inspections, repairs, and materials selections for a variety of FGD system components.</th>
<th>12/31/12</th>
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<tr>
<td>Application of EPRI Model to Predict and Control Steam-Side Oxide Scale Growth and Exfoliation: Tube failures and erosion damage from the release of steam-grown oxides from boiler superheater and re heater tubing continues to plague new plants and retrofit components. Material behavior differs between alloys, alloy class, and surface-finishing techniques (i.e., shot-peening). EPRI's model to predict and control steamside oxidation will be improved with the latest data and refinements from 2011 research. Improved guidance on temperature limits for materials to minimize tube failures will be researched and compared to data gathered during site visits.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Nanostructured Coatings for Erosion and Wear Protection of Power Plant Components: Initiation of Field Trials: EPRI has evaluated tough, adherent, dense, and hard nanocoatings, which show improvement compared to traditional coatings for wear, solid particle erosion, and liquid droplet erosion tests. EPRI has identified many possible applications for these coatings, including coal mills, tank impellers, steam turbine blades and vanes. EPRI will work with members who are experiencing wear and erosion issues to test the coating technology for the specific application by conducting field trials. The report will cover field trials initiated, in-plant performance, and post-trial observations as they become available.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Steam Turbine Valve Material Selection: Steam turbine valve stems, seats, and bushings often are selected based on manufacturer experience with alloys in other steam turbine components and the mechanical properties required. However, oxidation of valve stems and the tight clearances with bushings can cause valves to jam and stick, which is a constant headache for valve owners. Even if a material has good oxidation resistance, surface engineering techniques such as nitriding can improve wear resistance but decrease oxidation resistance. The interaction between these competing phenomena has not been studied in detail, and the limited studies suggest coatings or alternate materials may provide improved performance. Based on these observations, this project will conduct a test program for selection of optimum material combinations for combined oxidation, wear, and galling resistance between valve stems and bushing.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>
Supplemental Projects

Corrosion in Wet Flue Gas Desulfurization Systems (071261)

Background, Objectives, and New Learnings

State-of-the-art flue gas desulfurization (FGD) technologies have been or are being installed on most large coal-fired electric generating units in response to new regulatory emission requirements. Aggressive corrosion has been noted in some of these systems, presumably from the low-pH, high-chloride environments created in the FGD process. A variety of materials (metallic, organic, plastics, coating) are available to construct these systems, but due to cost, fabricability, and availability, the absorber vessels, tanks, piping, and spray towers in many new installations have been constructed using duplex stainless steel Alloy 2205, which had not been used on systems constructed before 2004. Unfortunately, many of these newer units are experiencing severe corrosion attack in operation over as little as three months. The primary mode appears to be pitting in weld heat-affected zones (HAZ), weld metal, and “under deposit” areas. Some corrosion due to surface contamination and surface finish (crevice corrosion) also has been reported. Some reports suggest this corrosion will extend to other duplex and standard stainless steel alloys.

This project will collect data on FGD units experiencing problems to determine the root cause(s) of the corrosion. Information on fabrication techniques, construction quality assurance/quality control, and operating environments (chemistry and scaling) will be gathered at as many sites as possible. These data will be used to identify gaps in knowledge, and missing data will be generated using laboratory and field corrosion tests for Alloy 2205, welds, and alternative materials/coating systems. Repair strategies and other mitigation strategies will be explored and documented if proven and widely applicable.

Project Approach and Summary

Determination of root cause(s) will utilize available information from currently known failures, identify missing data or information, and where possible, include inspection of several sites. A survey to collect information on materials and fabrication practices, including vessels and piping systems, is currently under way. It is anticipated that additional laboratory and field testing of materials will be necessary, which could include stainless steels, duplex alloys (2205), nickel-based alloys, welds/weldments, surface preparation/finishes, and coatings.

Fabrication guidelines for metallic FGD systems will be prepared, covering proper construction practices, contamination and surface acceptance, and welding practices for metallic materials. Repair options will be identified, including inspection, post-corrosion cleaning, and surface preparation.

A new Corrosion in FGD Materials Interest Group will hold a minimum of two meetings a year to provide a forum for ongoing exchange of information, ideas, and performance.

Benefits

The mitigation and repair of FGD vessels experiencing corrosion are critical issues. Failure of these vessels can result in potential damage to adjoining equipment and lost generation if the FGD system becomes inoperable.
Weld Repair of Grade 91 Piping & Components (071850)

Background, Objectives, and New Learnings

Grade 91 steel is one of a family of creep-strength-enhanced ferritic steels (CSEF). This steel now is routinely installed in both fossil-fuel-fired and combined-cycle units. Recent in-service experience has demonstrated that cracking can occur in CSEF early in life. The reasons include improper heat treatment of welds and components; design or construction practices that result in local stress concentrations; local operating conditions that are unexpectedly severe due to thermal transients or the presence of system loading; and difficulties associated with dissimilar metal welds.

Project Approach and Summary

This project builds directly on the understanding developed in the life management work. R&D will establish key information on removal of damage and approaches for repair welding. Selected variables and weld processes will be investigated and test programs will link performance to details of how the repair was carried out. This is important because, in contrast to traditional low-alloy steels that are relatively "user friendly" for repairs, CSEF steels introduce an additional complication: the properties and performance of the base metal are critically dependent on the original composition and the full heat treatment history. This aspect is so important that concerns have arisen that the repairability of steels such as Grade 91 will be limited.

Many possible variations are associated with making these repairs, including condition of the parent; degree of tempering (i.e., hardness); and level of creep damage present in the weld metal, heat-affected zone (HAZ), and parent. This project will address a number of key questions:

- What are the most appropriate methods for material removal, and what should be the extent of the excavation
- What welding process should be used
- What is the best method of filler metal selection and optimization of bead sequence and welding parameters
- Can welds be performed using temper bead welding followed by a minimum PWHT

Benefits

A recent EPRI project has successfully established the background technology necessary for approaches that ensure high-quality components are supplied and installed. In addition, this work delivered a life-management strategy that is both practical and effective in preventing in-service failures. However, large numbers of current components are susceptible to cracking. In the majority of cases, the defects will need to be repaired using fusion welding. The current project will examine key variables involved in repair decisions and quantify which of these variables has the greatest influence on subsequent performance. This knowledge will permit utilities to minimize the time and costs associated with making a repair while maximizing the potential that the repair will provide at least adequate in-service performance.
Life Management of Boiler and Piping Components Fabricated from Grade 92 Steels (071851)

Background, Objectives, and New Learnings

Work to date on Grade 92 steel has demonstrated that this creep-strength-enhanced ferritic (CSEF) steel will be susceptible to many of the problems that have been found in Grade 91. Problems have been identified with incorrectly controlled heat treatment, inadequate quality assurance during fabrication and installation, and Type IV cracking in the heat-affected zone (HAZ) of welds. Additional challenges will significantly influence longer-term damage, including:

- Very-low-ductility creep failure of base metal samples has occurred, which significantly raises concerns over catastrophic fracture, and
- Issues associated with creep failure of welds. It appears that creep failure can occur in the weld metal, depending on the post-weld heat treatment conditions used.

Project Approach and Summary

This project will build directly on the understanding developed in the work performed to date studying the life management of Grade 91 steel. Specifically, work on Grade 92 steel will be undertaken to:

- Establish key information on how the composition and heat treatment of the parent affects microstructure, strength, and ductility;
- Establish links between microstructure and development of damage under service conditions; and
- Examine how key variables associated with weld manufacture influence creep life and in-service failure.

The level of work performed will depend on the participation in the project. The following outline shows key potential issues that can be included. The details of the final scope will be established at the project initiation meeting with the sponsors.

The work will be considered in two complementary tasks:

Task 1: Parent Steel Issues

In addition to heat treatment influences, possible metallurgical issues include N:Al ratio and variation of elements that will influence the presence and extent of ferrite. It is anticipated that at least two parent compositions will be selected, and the samples will be renormalized and then tempered. Potential variables include normalizing temperature, cooling rate, tempering temperature, and time. The tempering conditions will be selected to reflect normal tempering and then a range of over-tempers.

For each condition, optical metallography and hardness testing will be performed. This will lead to a microstructural atlas and a tempering master curve, linking softening to thermal exposure. Selected samples also will be long-term aged to examine the effects of aging in the absence of applied stress and strain. Creep testing will be carried out on selected samples. The testing conditions will be used so that damage is representative of long-term service. Samples will be taken to failure and also interrupted at known life fractions so that the development of damage can be studied. Creep-tested parent samples available from previous work will be examined metallographically.

Task 2: Weld Performance

Thick section welds will be manufactured in the selected parent. It is expected that the welds will be manufactured using at least two different processes. For each process, potential variables include consumables, bead size, sequence, and post weld heat treatment. In each case, for all welds made, characterization will include optical metallography, electron microscopy, hardness testing, measurement of mechanical properties, assessment of creep behavior, quantification of damage development, and assessment of factors affecting fracture.
Benefits

A current EPRI project has successfully established the background technology necessary to underpin significant improvements in approaches for ensuring that high-quality Grade 91 steel components are supplied and installed. This project will deliver a practical life-management strategy for Grade 92 steel, which provides the basis for cost-effectively preventing in-service failures.
Instrumentation, Controls, and Automation - Program 68

Program Overview

Program Description
Power generators need to improve their ability to detect damage to plant equipment while preserving the focus of skilled instrumentation and controls (I&C) staff on plant operations and system performance. Additional sensors are needed to improve equipment condition monitoring, enabling optimization of maintenance tasks. Control systems have evolved from analog to digital, with new technologies to improve plant performance and operational effectiveness.

The Electric Power Research Institute’s (EPRI’s) Instrumentation, Controls, and Automation program (Program 68) identifies, develops, and demonstrates state-of-the-art sensing, monitoring, diagnostics, and control system technologies that improve equipment condition assessment and plant performance, and help accurately measure critical plant variables.

Research Value
Maintaining the availability of existing power generating plants and enhancing the performance of future plants are critical to the future generation portfolio. EPRI’s Operations and Maintenance programs address the key issues of operational effectiveness, safety, reduction of maintenance costs, and technical support for the next generation of plant staffs. The program focus is on providing integrated solutions that address the needs for processes, technologies, and skilled workers, allowing program members to:

- Reduce costs through greater automation in tuning of process controls and operating point transitions.
- Improve reliability through integrated anomaly detection, diagnostics, and prognostics.
- Improve reliability through more effective equipment monitoring, made possible through collaborative R&D.

Approach
Products developed by this program provide guidance through technical reports, guidelines, process specifications, webcasts, seminars, and workshops on research projects. Program activities address the identification, development, and transfer of new technology, and help optimize the use of existing instrumentation and control equipment, which can cost-effectively improve plant performance.

- Technology development and demonstration projects address critical aspects of fossil plant instrumentation and control systems, including advanced controls, automation, improved loop tuning, and equipment diagnostics. Applied research is conducted in collaboration with host sites at member utilities, expert consultants, universities, laboratories, and equipment vendors. The focus includes cyber security best practices to address industry standards; accurate detection and mitigation of equipment damage; increasing plant operational efficiency through the development and demonstration of control system improvements; and improved tuning processes that save time and improve consistency and staff knowledge capture.
- Technology Transfer projects provide peer-to-peer information exchange and written guidance on member-selected subjects, including online monitoring, sensors and instrumentation, controls, and automation. Fleet-Wide Monitoring Interest Group (FWMIG) meetings are held twice a year, and I&C interest group meetings are held once annually. Meeting materials—including presentations, minutes, and other related files—are distributed to all participants. The Instrumentation and Control Guideline addresses a member-selected topic annually.
Accomplishments

Successful implementation of online and automated monitoring technology for equipment condition assessment requires applied research conducted in collaboration with universities, laboratories, and equipment vendors. Field demonstrations of technology at operating plants have included combined-cycle plant automation, equipment startup automation, advanced control, and automatic tuning. The R&D in this program has provided:

- Successful Fleet-Wide Monitoring Interest Group (FWMIG), with more than 20 member organizations;
- Guidelines on instrument calibration data analysis, control loop tuning, and control loop performance monitoring;
- Technical reports documenting field demonstrations of new technologies relating to advanced control algorithms, automated controls tuning, multiloop controls tuning, and application of model predictive controls; and
- Technical reports documenting field demonstrations of sensors, wireless data transmission, and advanced anomaly detection algorithms.

Current Year Activities

The program R&D for 2012 will focus on using instrumentation and control system capabilities for improving operational flexibility, efficiency of critical control loops, and control system cyber security. Specific efforts will include:

- Technical report documenting best practices for establishing and operating a cyber security program for control systems;
- Continuation of the Fleet-Wide Monitoring Interest Group; and
- Technical report that will serve as a guideline for instrumentation and control processes key to operations and maintenance in power generating plants.

Estimated 2012 Program Funding

$0.9M

Program Manager

Aaron Hussey, 704-595-2509, ahussey@epri.com

Summary of Projects

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P68.001</td>
<td>Technology Development and Demonstrations</td>
<td>This project supports optimization of plant instrumentation and control systems, including cyber security, sensors, wireless technology, equipment diagnostics, advanced controls, automation, and improved loop tuning.</td>
</tr>
<tr>
<td>P68.002</td>
<td>Technology Transfer</td>
<td>Successful implementation of online monitoring technology and instrumentation, controls, and automation (ICA) technology requires peer-to-peer interaction among power producers and formal interaction with vendors.</td>
</tr>
</tbody>
</table>
**P68.001 Technology Development and Demonstrations (069177)**

**Key Research Question**

Many experienced instrumentation and control system experts in the industry are approaching retirement age, and less-experienced staff members are assuming their duties. At the same time, equipment is aging, plants are operated more aggressively than originally designed, and the industry is preparing for compliance with cyber security standards. Accurate detection and mitigation of damage, using existing control capabilities for flexible operations, and implementing cyber security program best practices are critically important for plant instrumentation and control systems.

**Approach**

This project develops and demonstrates plant instrumentation and control system technologies to solve today's critical industry issues. Modern control systems include a suite of technology capabilities that can be used to mitigate equipment damage and improve efficiency of operations. Applied research is conducted in collaboration with host sites at utility members, expert consultants, universities, laboratories, and equipment vendors. Field demonstrations of technologies at operating plants include wireless sensor networks, equipment fault diagnostics, combined-cycle plant automation, equipment startup automation, advanced control, and automatic tuning.

The research and development effort in 2012 and future years will focus on:

- Increasing plant operational flexibility and efficiency through the demonstration and evaluation of control system optimization technology, such as use of model predictive control and automated tuning methods;
- Improving control system cyber security by collecting and sharing best practices in establishing and operating cyber security programs that address industry standards, and;
- Improving equipment condition monitoring and diagnostics activities through addition of sensors, wireless networking, use of controls data, and integration of component degradation knowledge in online monitoring systems.

**Impact**

Instrumentation, controls, and automation technology R&D can improve plant staff knowledge and provide cost-effective evaluations of state-of-the-art technologies prior to full-scale implementation. Some examples of technology developments and demonstrations include:

- Automation of equipment and processes improves the consistency of startups/shutdowns, helps capture expert knowledge, and reduces equipment damage.
- Improved control system performance leads to more responsive plant operation, better efficiency, reduced emissions, and reduced likelihood of damaging temperature transients.
- Multiloop tuning methods result in significantly better control systems performance and lead to better, more robust tuning of boiler control systems.
- Automation of control system tuning methods improves consistency and enables the expertise of control engineers to be applied on a broad scale.
- Wireless sensor networking can reduce the cost of installation of additional sensors, enabling more effective detection of critical equipment failure modes.

Experience gained through this research will be directly applicable to both existing plants and new plant designs, enabling more effective application of online monitoring technology to create "smarter" components.

**How to Apply Results**

End users of this research include system engineers and owners, instrumentation and controls engineers, centralized monitoring staff, and technicians at fossil power plants. Some technology results will be published in the form of technical reports, guidelines, and process specifications that specify the proper approach for implementation of instrumentation, controls, and automation technology. Other technology results will be delivered as spreadsheets, databases, and presentation materials for quick review capability and ease of use.
Without this documented guidance, benefits of applying instrumentation, controls, and automation technology may not be realized to the full potential. In addition, key research results will be communicated periodically through webcasts, teleconferences, and face-to-face meetings.

### 2012 Products

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<tr>
<td><strong>Cyber Security Best Practices for Instrumentation and Control Systems:</strong> This project will begin a study on cyber security programs that utilities are implementing to meet industry standards. The focus is to identify and document industry best practices in mitigating security risks to I&amp;C systems.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<tr>
<td><strong>Monitoring and Test Methods to Identify Pulverizer Response Problems:</strong> This project will complete the second year of study of the impact of pulverizer performance on load response and identify a mechanism to easily test a pulverizer online to determine its responsiveness (or change in responsiveness). Results will be used to determine if the pulverizer needs maintenance or if the control system needs tuning.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<td><strong>Using Control Methods to Accommodate Changing Coal Quality:</strong> Coal quality variation from coal blending and other mechanisms causes process variations for which the boiler controls were not originally tuned. Advanced control technology, including adaptive control, might help to consistently control boiler systems within given constraints when changes to fuel heating value, moisture, and other characteristics occur. This study will investigate controls solutions for this problem and collaborate with other related research programs.</td>
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<td><strong>Optimizing Sensor Placement to Infer Spatial Patterns:</strong> Optimal placement of heat flux and oxygen sensors in boilers is a key determination, often based on access and cost considerations. However, the most optimal placement could be determined through proper modeling for spatial patterns that can be measured through an optimized number of sensors.</td>
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<td><strong>Drum Level Control Solution for Combined-Cycle Startups:</strong> During startup, closing the feedwater valves is not always sufficient to prevent high levels in the drum. As a result, operators anticipate this problem and lower the level setpoint with the hope of preventing water carryover. This project would investigate a control or automation solution to this problem.</td>
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Optimizing Sensor Placement to Infer Spatial Patterns: Optimal placement of heat flux and oxygen sensors in boilers is a key determination, often based on access and cost considerations. However, the most optimal placement could be determined through proper modeling for spatial patterns that can be measured through an optimized number of sensors.

12/31/14 Technical Report

P68.002 Technology Transfer (065777)

Key Research Question

Plant owners demand more efficient operation and effective maintenance to reduce production costs and improve availability. Successful implementation of online monitoring technology and instrumentation, controls, and automation (ICA) technology requires peer-to-peer interaction among power producers and formal interaction with vendors. Technology gaps must be identified by end users to guide development and demonstration efforts.

Approach

Held twice a year, Fleet-Wide Monitoring Interest Group (FWMIG) meetings offer open peer-to-peer information exchanges and formal presentations by vendors on member-selected subjects. Meeting materials—including presentations, minutes, and other related files—are distributed to all participants. The FWMIG will guide EPRI projects on centralized online monitoring and diagnostics technology.

A technical update, Instrumentation and Controls Guideline, is issued annually on member-selected topics. These topics may include instrumentation, calibration, controls, automation, sensors, online monitoring, and wireless technology. The focus of these reports is on best practices in the electric utility and other industries. As funding permits, assessments of emerging technologies and their early adoption in power-producing facilities is conducted through webcasts and documentation in the form of technical updates.

Additional peer-to-peer exchange of ICA topics takes place during interest group meetings held in conjunction with industry conferences, or at host sites/EPRI facilities as funding permits. Newsletters are published, and webcasts are presented as necessary to communicate key technology transfer activities and progress on projects.

Impact

- Peer-to-peer information sharing improves technology implementation in emerging areas, such as online monitoring and ICA technology.
- Collaboration among utility members, vendors, and researchers results in more effective technology development.
- Sharing experiences from early technology adoption in other industries benefits power producers.

How to Apply Results

End users of this research include system engineers and managers, control systems engineers, and technicians at fossil power plants. Interest group meetings are held periodically to enable open information exchange among members in key strategic areas affecting utilities. ICA technology guidelines are published in the form of technical update reports and are used as guidance when reviewing or improving key plant ICA processes. Key research results are communicated periodically through webcasts.
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Supplemental Projects

Fleetwide Monitoring Interest Group (063807)

Background, Objectives, and New Learnings

The Fleet-Wide Monitoring Interest Group (FWMIG) was formed to enable open information exchange between utility members, vendors, and researchers on all aspects of fleet-wide monitoring. Topics covered by this interest group include equipment condition monitoring, thermal performance monitoring, operations and maintenance (O&M) effects of a fleet-wide approach, cost-benefit analysis, and ongoing discussions on R&D and technology gaps.

Project Approach and Summary

The FWMIG meets twice per year, with participants representing utilities, vendors, universities, and EPRI. Meeting topics include updates on activities in other industries as well as monitoring applications within the power industry. Participants present the latest progress made in fleet-wide monitoring implementations. The meeting agenda also includes a member roundtable to discuss open issues in the application of fleet-wide monitoring tools.

As part of the roundtable, gaps that can be addressed by research projects are discussed. These gaps will be formulated into additional supplemental projects with specific scopes and approaches, which will be carried out separately from the interest group.

A website bulletin board will provide a forum for correspondence among members as well as an archive of meeting materials and links to related projects.

Benefits

Unplanned and/or corrective maintenance of power industry equipment remains one of the most significant O&M expenses, sometimes resulting in unplanned outages and reduced financial margins due to increased replacement electricity costs. Online equipment condition monitoring can provide early warning of potential failure by detecting incipient leading indicators of equipment degradation via powerful signal processing applied to existing instrumentation.

EPRI's role in fleet-wide monitoring is to bring its knowledge of equipment reliability and understanding of equipment failure modes and effects to participants of this interest group. The objective is for equipment condition monitoring software to be applied on a fleet-wide basis to move it closer to a "plug and play" mode of operation. This advancement should measurably reduce maintenance efforts and costs, improve reliability, and increase customer and investor confidence.
HRSG Damage Reduction through Improved Controls (072046)

Background, Objectives, and New Learnings

Many combined-cycle units are cycling much more than anticipated in the original design basis. Problems resulting from increased cycling include accelerated component failure rates and additional incremental fuel cost. In combined-cycle units, as with coal-fired units, superheat and reheat spray attemperation introduces the potential for serious component degradation and failures in piping, headers, and tubes. On many combined-cycle units, the superheater (SH) and reheater (RH) controls strategies are based on designs long used in coal-fired plants. Due to the faster response time of combustion turbines, these control design philosophies are not necessarily adequate, in particular in those that do frequent cycling. As a result, a significant number of heat recovery steam generator (HRSG) failures have been experienced worldwide that have at least been attributed partly to inadequate attemperation control.

The primary objective of this project is to investigate and implement advanced instrumentation and control (I&C) strategies to mitigate the adverse impacts of inadequate steam temperature control. This research will include thorough investigations of control strategies and instrumentation and control hardware and their overall effects on steam temperature control performance, followed by implementation and evaluation.

Project Approach and Summary

To meet the overall objective of this project, the following approach is envisioned:
1. Document existing controls and their performance
2. Identify candidate I&C improvements
3. Perform detailed design of identified improvements
4. Implement identified improvements
5. Test and evaluate benefits
6. Document the entire effort in an industry report

Potential I&C improvements include advanced control algorithms such as automatic proportional-integral-derivative (PID) tuning, model predictive control (MPC), additional traditional and novel instrumentation, and primary control element modifications.

Benefits

Using the results of this research, steam temperature control optimization could better reduce damage to equipment (valves and piping,) and help improve the reliability, costs, and environmental impact of power generation through:
- Performance and heat rate improvements and fuel cost reductions
- Reduced fuel consumption through improved thermodynamic efficiency
- Increased availability of power generation through reduced unplanned outages due to equipment failure
Cyber Security Solutions for Instrumentation and Control Systems (071911)

**Background, Objectives, and New Learnings**

Information technology (IT) practices for personal and business networks require continual updates to mitigate threats from cyber attacks. Antivirus programs, firewalls, passwords, and encryption are familiar technologies protecting our personal and business networks. But even with all of these mitigation technologies, cyber attackers continue to find ways to penetrate computer systems. Such attacks pose significant risks when directed at power plant control systems, particularly those at generating units that are critical to production.

IT security policies and practices are well-established, with professionals working to secure business networks while constantly increasing workplace productivity. Although industrial control systems (ICS) share much of the same type of computing technologies as business networks, security policies and practices must consider a different type of productivity requirement – safety and efficiency of process control. Control engineers are required to maintain, upgrade, and secure control systems while also optimizing their end use by plant operators.

Cyber security standards have been produced as a result of continual threats to business and process control networks. Many standards have been drafted, undergone revision, and are being enforced for compliance. In recent years, electric utilities have established cyber security programs to ensure compliance with critical infrastructure protection (CIP) standards requirements of the North American Electric Reliability Corporation (NERC) and related requirements in the international community.

Compliance with these standards is not easy, and requires IT staff and control engineers to work together to implement and maintain a cyber security program for control systems. As part of establishing and maintaining a cyber security program, a variety of security strategies and technologies are needed to mitigate risk and react to new vulnerabilities while improving program efficiency.

The objective of this project is to investigate and document solutions for control system security. This work will enable effective application and foster new technology developments.

**Project Approach and Summary**

This project will explore and document a variety of solutions for securing instrumentation and control systems. The focus will be on solutions implemented in the fossil power industry, and solutions from other industries also will be considered. For each solution topic, the project team will study how the technology works, implementation options and best practices, field installations, and capabilities/limitations.

EPRI will work with participants to establish and prioritize solution topics to study, and will address the top three. A preliminary list includes:

- Data diodes
- Automated change management
- Remote access
- White listing of applications
- Wireless sensor network security
- Active control network scanning
- Hardening cyber assets
- Patch management
- Ports and service management
- Security status monitoring
- USB memory stick protection
- Use of active directory
- Virus/malware protection
EPRI will research and summarize all existing industry documentation for the topics selected with a focus on implementation best practices, technology gaps, and new developments.

**Benefits**

Cyber security strategies and technologies will reduce vulnerabilities of power plant control systems to malicious attacks that could cause disruption to electricity generation and damage to equipment. Technology-assisted early detection and prevention of cyber attacks can ensure reliable, safe, environmentally sound, and economic operation of critical generating units.

Participants in this project will gain new knowledge and receive practical implementation guidance for a variety of options for establishing required control system security. This guidance can improve participants’ abilities to address elements of cyber security standards through improved understanding of strategies and technology options.

The project will include an assessment of actual field application of specific strategies for achieving control system security.
Program Overview

Program Description
Existing electric power generating units meet an important strategic need. To continue to meet the load demands of the bulk electric power system, the current fleet of generating units must remain highly available, reliable, and efficient. As the industry landscape shifts, achieving these goals will become more challenging. Increasingly greater demands are being placed on plant staffs to meet these availability, reliability, and efficiency standards, even as those staffs are becoming leaner and less experienced due to retirements, mergers and acquisitions, unit closings, and other events that significantly alter the size and demographics of the workforce. Many units are being operated under conditions, such as the number or types of transient conditions now being experienced, and/or the sheer age of the units, to which they have never been exposed. These changes produce an entirely new dynamic for organizations that only adds to the plant maintenance challenges they face.

The Electric Power Research Institute’s (EPRI’s) Maintenance Management and Technology program (Program 69) helps plant owners and operators address this challenging environment by developing best practices associated with maintenance program structure and functionality. Collaborative research involving top-performing organizations is used to develop maintenance processes that identify causes of potential equipment failures, effective monitoring and assessment of equipment condition, and proactive planning for equipment maintenance. EPRI assists member companies in more effectively utilizing their staffs by increasing their proficiency in applying standard processes, facilitating peer collaboration, creating databases to support condition-based maintenance, and documenting case histories.

Research Value
EPRI’s Operations and Maintenance programs help members transition to, and sustain, the least-costly procedures and practices associated with plant maintenance. The key attributes of an optimized program are adoption of information management needed to support a condition-based approach to maintenance, and replacement of costly corrective maintenance with proactive preventive maintenance. The focus of this program is on providing an integrated solution that addresses the needs for processes, technologies, and skilled people, which enables condition-based maintenance to support risk-informed maintenance decisions. By using the R&D in this program, members can:

- Achieve operation and maintenance excellence through an integrated approach that includes process improvements, related technologies, and knowledge management;
- Address current issues associated with the need for flexible plant operations, asset retirement, and new reliability standards;
- Achieve Lean maintenance through reduced use of resources; and
- Increase plant availability and reliability through improved outage management and staff performance.

Approach
The ongoing evolution of enhanced plant maintenance processes and technology is an inherently collaborative activity, involving member companies, industry experts, and EPRI staff. Involvement in the program as an advisor or participant in the various projects and user groups is the primary means by which value is received from EPRI. The project structure established to help facilitate this transfer of results includes:

- User groups, meetings, and workshops that provide a structure for sharing peer information about, and experience with, plant maintenance. These venues include the Plant Reliability Interest Group (PRIG), Condition-Based Maintenance User Group (CBMUG), and the Plant Manager Forum.
Plant maintenance processes that focus on development and improvement of both fundamental and new best practices experienced throughout the industry. Technical reports cover detailed aspects of the primary process elements such as condition-based maintenance, work management, maintenance basis, outage planning/execution, human factors, corrective action, and continuous improvement.

Plant maintenance technology R&D that facilitates the deployment of advanced maintenance processes, which are essential to achieving desired performance. This R&D includes technologies to support the identification and optimization of preventive maintenance (PM) tasks, the management of predictive maintenance (PdM), diagnostics, prognostics, and risk management. The software products in this project provide databases that members can use to apply component and system knowledge and perform effective equipment analysis.

Accomplishments

Maintenance engineers, planners, and system owners need information, technologies, and processes to achieve high performance in plant availability, reliability, and efficiency while effectively minimizing production costs. This program has provided:

- Development and application of plant reliability processes and standards at members’ facilities;
- More than 100 technical reports, technical updates, and software products that cover all aspects of preventive/predictive maintenance, work planning, work execution, outage management, and human performance;
- A widely used enterprise software tool, PlantView, which facilitates sustained high performance derived from integrating process elements such as maintenance basis, predictive maintenance, system health, and risk assessments; and
- A cutting-edge software package to facilitate integrated equipment diagnostics (Asset Fault Signature Database and Diagnostic Advisor) and prognostics (Remaining Useful Life Database and Remaining Useful Life Advisor). These products include databases of known equipment fault indicators and failure models that are used to assist plant staff with both the diagnosis and prediction of plant equipment failures.

Current Year Activities

The program R&D for 2012 will maintain the focus on improvements in maintenance processes and related technologies. Specific research subject areas will include some of the following topics:

- Guidelines for developing a preventive maintenance (PM) program
- Human performance improvements for the next-generation workforce
- Managing condition-based maintenance programs at combustion turbine (CT) and combined cycle (CC) units
- Managing condition-based maintenance programs for renewable generation technologies
- Developing software to facilitate the identification, prioritization, and implementation of preventive maintenance (PM) tasks
- Developing the production version of the Remaining Useful Life (RUL) Database
- Developing criteria for analyzing and assessing predictive maintenance (PdM) data
- Application and implementation of designated maintenance processes

Estimated 2012 Program Funding

$1.5M

Program Manager

Brian Hollingshaus, 704-595-2579, bholling@eprisolutions.com
Summary of Projects

<table>
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<tr>
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<td>P69.001</td>
<td>User Groups, Meetings, and Benchmarking</td>
<td>This project provides a collaborative forum for exchange of information relating to implementation of advanced fossil plant maintenance strategies, processes, and related technologies.</td>
</tr>
<tr>
<td>P69.002</td>
<td>Fossil Plant Maintenance Processes</td>
<td>This project assists members in achieving improved equipment reliability, reduced O&amp;M costs, and efficient workforce utilization through development and implementation of advanced maintenance processes.</td>
</tr>
<tr>
<td>P69.003</td>
<td>Fossil Plant Maintenance Technology</td>
<td>This project conducts research to identify, develop, and apply emerging technologies that support improved fossil maintenance management processes needed to ensure viability of the existing fossil fleet.</td>
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P69.001 User Groups, Meetings, and Benchmarking (062022)

**Key Research Question**

Maintenance managers, planners, system owners, engineers, and plant managers need access to information about proven processes, organizational strategies, related technologies, and successful applications to help sustain high performance in plant availability, reliability, and production costs. Obtaining this information requires participation in workshops, conferences, technical webcasts, and user groups that enable peer information exchange and technology gap identification. Collaboration to share best practices and provide a basis for self-benchmarking is essential to improving plant reliability.

**Approach**

Technical workshops and conferences provide a structure for sharing peer information about, and experience with, plant maintenance. Webcasts are used to engage plant-level maintenance staff. Meetings include the Plant Reliability Interest Group (PRIG), EPRI’s annual EPRI Condition-Based Maintenance conference (CBMUG), the semi-annual Plant Manager Forum meetings, and various workshops and training in new technologies. An annual compilation of key findings from all maintenance-related meetings is assembled and provided to program members.

**Impact**

- Addresses organizational and human performance barriers to sustained high performance in areas of cost and reliability
- Provides tools and information to plant management to address today's business challenges
- Provides access to industry-proven procedures and practices through participation in workshops, conferences, and webcasts
- Identifies implementation strategies pertaining to advanced maintenance processes and related technologies to improve plant reliability

**How to Apply Results**

Members receive value from this project by participating in the Plant Reliability Interest Group, Plant Manager Forum, the annual EPRI Condition-Based Maintenance conference, topical webcasts, and training sessions. Members are encouraged to perform self-assessments and benchmark using best-practices and metrics shared by participating peer companies, as well as EPRI staff and other industry experts.
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| **User Group Meetings Proceedings and Key Findings:** EPRI sponsors a number of meetings, workshops, and conferences each year relating to maintenance topics. These events include the Plant Reliability Interest Group, EPRI's annual Condition-Based Maintenance Workshop, Plant Managers Forum, Equipment User Groups, and topical webcasts. At each of these meetings, a set of key findings is developed that result from discussions and meeting presentations. This Technical Update report will assemble these key findings throughout the year for meetings, workshops, and conferences relating to Program 69. This information will be organized and formatted into a meeting synopsis and documented in this annual Technical Update that allows easier access to these key takeaways. | 12/31/12 | Technical Update |

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**P69.002 Fossil Plant Maintenance Processes (062023)**

**Key Research Question**

Owners and operators of electric power generating units strive for effective and efficient maintenance processes to ensure optimum reliability and productivity of their fleet. To achieve this goal, these organizations need to sustain the optimum balance of corrective, preventive, predictive, and proactive maintenance activities in a streamlined, process-oriented program. Adoption of improved maintenance processes provides significant benefits to member organizations through Lean management principles, improved quality of maintenance, reduced outage durations, avoided unplanned downtime, and enhanced safety. The need to sustain a high level of plant performance will increase in the future as aggressive dispatching strategies will challenge equipment reliability, while at the same time reducing budget resources available for nonfuel operations and maintenance costs.

Advanced management practices are needed throughout the industry in areas such as outage planning/execution, preventive maintenance, backlog management, work closeout, inventory management, and human error reduction. Ongoing collaboration between member organizations and EPRI ensures that the processes and practices developed in this project can be adopted in today's fossil power industry business climate.

**Approach**

This project focuses on maintenance process development and continued improvement. EPRI works with member companies to identify gaps and improvement opportunities relating to the specific needs of today's electric power generation industry. Solutions and best practices are developed that optimize plant performance by balancing equipment reliability and maintenance costs. An emphasis is placed on condition-based maintenance processes used to facilitate risk-informed decision-making. Technical reports define desired characteristics of the primary process elements such as work management, predictive maintenance, maintenance basis, outage planning/execution, optimal capital resource allocation, and continuous improvement. This project is increasingly focused on helping organizations transition to improved processes, and then sustain high performance.
Impact

- Significant benefits in plant availability and production costs can be achieved through the implementation and sustained improvement of maintenance processes.
- Plant availability can be increased by reducing outage duration through better planning and reduced rework due to improved execution of maintenance tasks.
- Standard maintenance processes are more easily adopted across fleets of generating units, leveraging scarce technical resources and ensuring consistent criteria for use of capital and operations and maintenance budgets.
- Documentation of structured maintenance processes provides valuable references for new staff members in planning and executing maintenance activities.

How to Apply Results

Members who participate in EPRI as technical advisors in process development initiatives can more easily integrate findings and processes from this project into their plant maintenance programs. In addition, technical reports produced by this project are valuable reference guides and serve as instructional tools for new staff. This project continually explores new ways to assist members in implementing advanced process elements across member organizations—for example, through enterprise software tools and supporting databases.

2012 Products

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<td><strong>Guidelines for Developing a Preventive Maintenance (PM) Program:</strong></td>
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<td><strong>Identifying, Prioritizing, and Implementing PM Tasks:</strong> This technical report is intended to provide a description of EPRI’s process for identifying, prioritizing, selecting, and implementing preventive maintenance (PM) tasks to comprise a PM program. Various initiatives over the past decade address elements of this process. EPRI has continued to refine these different approaches to establish best practices associated with developing or reassessing PM programs. This technical report will illustrate these best practices.</td>
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<td><strong>Managing Condition-Based Maintenance Programs for Combustion Turbine (CT) and Combined Cycle (CC) Units:</strong> Condition-based maintenance (CBM) programs have become an intricate part of operating pulverized coal generating units. These programs allow organizations to identify maintenance strategies that emphasize monitoring and assessing the condition of equipment to determine maintenance activities. These programs require extensive knowledge of plant equipment, including what can fail, why it will fail, and how it can be monitored. They also require extensive capabilities regarding how data is collected, managed, assessed, and used to make actionable maintenance decisions. As the landscape of electric power generation changes, combustion turbine (CT) and combined cycle (CC) units are becoming more valuable and utilized assets. Just as it did for pulverized coal units, CBM has the potential to affect CT/CC units to improve the efficiency and effectiveness of maintenance on these assets. This technical report is intended to explore how lessons learned from pulverized coal units can be applied to CT/CC units, as well as where current gaps still exist.</td>
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Managing Condition-Based Maintenance Programs for Renewable Generation Technologies: Condition-based maintenance (CBM) programs have become an intricate part of operating pulverized coal generating units. These programs allow organizations to identify maintenance strategies that emphasize monitoring and assessing the condition of equipment to determine maintenance activities. These programs require extensive knowledge of plant equipment, including what can fail, why it will fail, and how it can be monitored. They also require extensive capabilities regarding how data is collected, managed, assessed, and used to make actionable maintenance decisions. As the landscape of electric power generation changes, renewable generation sources will become more valuable and utilized assets. Just as it did for pulverized coal units, CBM has the potential to affect renewable generation sources to improve the efficiency and effectiveness of maintenance on these assets. This technical report is intended to explore how lessons learned from pulverized coal units can be applied to renewable generation sources, as well as where current gaps still exist.

Strategies for Human Performance Improvements for the Next Generation Workforce: Organizations currently are experiencing a transition in workforce demographics. New plant personnel have new and different skill sets, as well as less technical experience. This product will focus on techniques to improve the human performance element of this new workforce, and leverage its capabilities derived from these new and different skills.

Risk-Based Spares Management Strategies: Spares management requires an effective decision-making process that seeks to optimize the cost and benefit associated with the inventory. This report will focus on identifying applications of a risk-informed process to the management of equipment spares. Specific emphasis will be given to the financial implications of keeping certain spares in stock versus other alternatives.

Configuration Management for New Fossil Power Plants: The future operating costs, reliability, and safety of today’s newly commissioned power plants will be strongly influenced by institution of a disciplined approach to plant configuration management. It is vitally important to not “get behind” in this process, which would require a costly future effort to bring records up to date. This technical report will outline strategies that can be cost-effectively employed today to maintain effective configuration management into the future. New technology solutions will be described, as well as the potential role of computerized maintenance management system (CMMS) in integrating configuration management into the daily work.

Effective Communication Strategies to Sustain Operations and Maintenance Process Improvements: Plant reliability initiatives require organizations to disseminate a structured vision and strategy throughout multiple levels of the organization. Steering teams must convey the strategies and concepts to incorporate technical teams, plant management teams, plant technical personnel, and many other types of employees. This product will identify best practices for spreading these strategies and concepts to these different levels. Communication packages will be developed that target a variety of personnel.
Guidelines for Creating Corporate Directives to Support Fossil Plant System Reliability Programs: One of the most influential aspects of a reliability improvement program or initiative is executive foresight and support. One key resource that helps organizations explicitly illustrate this executive sponsorship is a corporate directive. EPRI currently uses templates to create these directives for programs such as Boiler Tube Failure Reduction (BTFR). This product will consist of templates for each of the plant systems that are consistent with the format and structure of the BTFR corporate directive.

Comprehensive Maintenance Program Model: A technical update report will be issued in December 2010, documenting the development progress of a standard maintenance program model. This model is intended to provide the ability to assess and compare current aspects of a company's maintenance program, as well as identify opportunities for improvement. Although such models exist in certain sectors of the power industry, fossil power generation lacks any form of standardized process model. This model will provide a unifying framework to which all other programs/initiatives (plant reliability optimization, maintenance optimization, and outage management) can be mapped. Further development of this model will continue in 2013, focused on specific elements and processes within a maintenance program.

P69.003 Fossil Plant Maintenance Technology (062024)

Key Research Question

Technology is a vital element in that it can significantly improve efficiency. Technology also has the ability to standardize and dictate how processes function. Plant maintenance is an area greatly influenced and improved by the use of technology. Technology primarily is used to support information management in areas such as predictive maintenance (PdM), work management, equipment diagnostics, equipment health, and risk assessment. Technology solutions must be cost-effective and easily integrated with existing enterprise systems. Technology gaps inhibit many maintenance organizations from maximizing their performance capabilities.

Advancements in maintenance technology will improve the ability of plant personnel to conduct condition assessments of plant equipment, diagnose equipment anomalies, and utilize risk management practices. This improvement will allow plants to optimize the use of scarce resources and maximize availability. The challenge to sustaining a high level of plant performance will increase as plants are cycled, new tighter regulatory restrictions are applied, and investors demand continued reductions in operating costs.

Approach

This project seeks opportunities to apply emerging technologies to address industry needs in plant maintenance processes. In some cases, process improvements developed under Project 69.002 (Plant Maintenance Processes) are considered as candidates for development of technology to assist implementation. The research and development in this project includes:

- Development and demonstration of new databases for supporting maintenance decision-making. These databases include those that apply component and system knowledge to fault diagnostics, as well as databases that supply information related to prognostics and equipment remaining life.
- Other technology topics that support work execution, predictive maintenance, scheduling, and configuration management.
Impact

- Using information technology to integrate predictive maintenance with component and system health provides a basis for performing the right maintenance at the right time.
- Technology that facilitates the assembly and dissemination of key information on component health and risk of failure will enable more efficient use of maintenance resources and capital.
- The creation of shared industry databases that support fault diagnoses and remaining useful life assessment can effectively share knowledge and expertise from a broad segment of the fossil power industry.

How to Apply Results

Results of this project can be implemented as information databases that support advanced maintenance process elements such as diagnostics, prognostics, and risk-informed decision-making. In addition, technical reports or webcasts will assess emerging technology in related industries and strategies for successful implementation in fossil power generation. Peer collaboration at meetings such as the Plant Reliability Interest Group, the Condition-Based Maintenance User Group, and the Plant Manager Forum will enable sharing of best practices related to technology application.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Maintenance Basis Optimization Software: As part of the ongoing effort to help members use existing resources to improve reliability and cut costs, this project will develop a maintenance basis tool with a focus on determining the maintenance tasks of highest value and improving current task plans. This software tool will help members integrate the failure rate and task effectiveness data contained in more than 150 previous equipment data tables within their enterprise systems to optimize task strategies for all plant equipment. This tool will leverage the existing and proven optimization algorithms while providing a platform to include new reasoning and diagnostic capabilities delivered in other program offerings. The goal of the project will be to develop a tool that will eliminate the obstacles to developing comprehensive and informed understanding of the risks associated with each failure mode, and to develop a cost-effective strategy.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Remaining Useful Life (RUL) Database: In 2010 and 2011, EPRI developed the Remaining Useful Life (RUL) Database and RUL Advisor, first as a demonstration version of software, then as a test version of software. In 2012, EPRI will incorporate feedback from both previous versions of this software into the first production version of the software. This software will collect, store, manage, and provide information necessary for plant personnel to create remaining life estimations for all manner of plant equipment using a wide range of forecast methods or models. Following completion of the production version, content will continually need to be developed to populate the RUL Signatures contained within the database. This project will help create such signatures.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td>Criteria for Assessing Predictive Maintenance (PdM) Data: Technical personnel are required to collect predictive maintenance (PdM) data using a variety of technologies and numerous applications of the technology. Capturing this data and translating it into useful condition assessment information regarding the equipment is a vital aspect of the PdM process, but requires guidance through use of criteria. This product will provide the guidance to assist technical personnel in evaluating PdM technology data and translating this data into useful information.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>
Applications of Predictive Maintenance (PdM) Technologies: The traditional predictive maintenance (PdM) technologies (vibration, tribology/lubrication, infrared thermography, acoustics, and motor testing) are a fairly mature set of technologies. The extensive knowledge and understanding of these technologies represent a positive knowledge source for the industry; however, most applications of these technologies in electric power generation are for traditional equipment types in traditional systems in fossil or nuclear generating units. With the changing landscape of the power generation industry, new types of equipment and systems are being installed and operated. This project will explore applications of PdM technologies to these new systems and equipment types.

12/31/12 Technical Report

Functional Specification for Effective Integration of Technology Examination Data: Effective condition-based maintenance requires that predictive maintenance results and other technology examination data be effectively assessed and archived for efficient trending. Top-performing plants employ enterprise software to manage and standardize the process of turning technology examination data into component/system health and actionable information. This project will create a functional specification document that includes the essential elements of effective technology examination data processing in an enterprise software environment.

12/31/13 Technical Report

Specification for a Database to Support Maintenance Work Package Development: There is an ongoing need in the power generation industry is to improve the work planning capabilities of plant maintenance programs. Effective planning is central to reducing maintenance cost and avoiding rework. A resource that has been identified as a potential opportunity to improve planning is a database of work packages that includes standard templates for typical maintenance tasks. These templates would help guide new planners in generating improved work packages. EPRI will work closely with members to develop an outline of the desired specifications for this proposed template database.

12/31/13 Technical Report

Benchmarking Predictive Maintenance (PdM) Technologies: During the 1990s and early 2000s, Predictive Maintenance (PdM) became an integral part of power plant condition-based maintenance. Technologies and applications of these technologies were a significant focus for EPRI Program 69. The capabilities of PdM technologies and related data acquisition/processing have expanded significantly over the past decade. This product will focus on these changes and identify the newest PdM technologies, as well as the latest applications of existing PdM technologies that support Lean condition-based maintenance.

12/31/14 Technical Report
Supplemental Projects

Plant Reliability Interest Group (066929)

Background, Objectives, and New Learnings

Organizations in the electric power industry are faced with the task of designing and implementing plant programs and processes that promote optimal equipment reliability while minimizing operating and maintenance costs. The objective of the Plant Reliability Interest Group (PRIG) is to provide an active forum for Electric Power Research Institute (EPRI) member companies to share successful strategies related to the design and implementation of these programs and processes. The challenges of implementation can be successfully addressed by peer-sharing, and the generation of strategies that result can benefit all members of the group.

EPRI’s former Plant Reliability Optimization User Group (PROUG) served this industry need until 2010 by providing assistance with the implementation of the Plant Reliability Optimization (PRO) process. The new PRIG will continue this effort with the opportunity to broaden the scope to include emerging topics of generic interest to fossil plant maintenance such as Lean process principles and human performance improvement.

Project Approach and Summary

The intent of the PRIG is to provide a forum for participants—including generating plant, power delivery, and corporate personnel—to address common issues, problems, and resolutions related to proactive maintenance strategies. The value of the interest group is in sharing information between those seeking solutions and those who either have successfully implemented process improvements, or have a common interest in developing a solution. A series of sessions within the annual meetings will cover different aspects of maintenance and reliability, such as predictive maintenance, maintenance basis, and continuous improvement.

Benefits

Members who participate in the PRIG will share information on practical approaches to achieving plant reliability as well as the effectiveness of enabling technologies. Benefits of this interest group include: improved equipment reliability, optimized maintenance costs, and improved decision-making.
Guidelines for Managing Flexible Operation (071859)

Background, Objectives, and New Learnings
Reduced industrial demand and increased fuel price variability are forcing changes to fossil asset dispatching. In addition, increased deployment of renewable generation over the next decade will force coal and combined-cycle plants to provide system load-balancing service. Specific operational changes expected for coal and gas plants include two-shifting, high ramp rates, high unit turndown, and reserve shutdown. These operational changes accelerate damage mechanisms such as creep fatigue, thermal fatigue, and corrosion, increasing the rate of component life consumption. This wear-and-tear increases the overall costs of generation, including direct costs such as fuel, water treatment, and maintenance.

The project objective is to provide the industry with a comprehensive knowledge resource that can guide a successful transition to flexible operation. This project will facilitate utilization of existing EPRI research results on component-level cycling impacts and mitigation. In addition, the project will compile lessons learned and strategies used by organizations worldwide to address plant cycling. This collaborative approach to addressing industry needs will create new learning on plant impacts and mitigation strategies.

Project Approach and Summary
Proven strategies for managing the transition to flexible plant operation will be documented by engaging directly with experienced plant staff tasked with past projects. This information will be organized and integrated with key knowledge contained in past EPRI research to create a single industry resource. The organization and format of this resource will be developed collaboratively by project participants and EPRI to ensure that it addresses the industry needs. Access to this industry resource during its development will provide project participants timely information for use in their fleet flexible operation strategy development. This access by participants also will facilitate peer review of the resource content to ensure that it is operationally sound.

Benefits
A reliable supply of fossil-fueled electricity generation will remain strategically important in the worldwide generation mix. The transition to a lower-carbon asset mix will force existing conventional plants to adopt new operational practices. These new strategies will be essential to maintaining their economic viability.

Owners and operators of fossil power plants today will need to consider a range of strategies for managing the increasing need for flexible operation. Access to information on the impact of flexible operations on plant equipment, damage mechanisms, costs, and mitigation strategies can be vitally important to the staff assigned to manage transition to flexible operation.

Project participants will assist in the creation of a comprehensive information resource devoted to the management of flexible plant operations. Generating companies need ready access to information to educate a broad range of their workers on topics relating to the holistic management of flexible operation. Participants in this project will have access to such information, as well as opportunities to learn from experiences of peer companies and subjectmatter experts.
Occupational Exposure to Physical Stressors: Intervention and Prevention (072036)

Background, Objectives, and New Learnings

Occupational exposures to physical stressors such as noise are prevalent within the electric utility industry. During 1995-2009, the EPRI Occupational Health and Safety Database, which tracks illness and injury for eighteen member utilities, showed that hearing loss or impairment resulted in 3% of total utility worker injuries. If constantly exposed to noise, workers may experience progressive hearing loss slowly over time, which in turn may affect their ability to perform safely and translate to an indirect number of acute workplace injuries.

Noise-induced hearing loss has been implicated in workplace accidents. Auditory changes are progressive, possibly placing workers at risk for accidents. Traditionally, workers are enrolled in hearing conservation programs after an action level of 85 decibels (dB) is met. Noise surveys capture environments requiring action but are not conducted at multiple time points; consequently, noisy environments may be underestimated. According to published studies in the aluminum industry, annual audiometry data capture hearing loss once it has occurred and the most vulnerable workers actually may fall below the accepted permissible exposure limit. Since opportunities to intervene prior to hearing loss are limited using annual audiometry, data gaps exist for workers who may be just below 85 dB and who may potentially have preventable workplace hearing loss.

Workers may use personal protective gear such as ear muffs and ear plugs that modify exposure; hence, measured ambient or personal exposure levels may not reflect actual exposure. Novel in-ear dosimetry technology—devices that fit like an earplug and measure attenuated noise from within the ear canal—could be used to address worker discomfort and potential exposure modification issues. In addition, the dosimeter could be programmed to advise the worker and/or her/his supervisor when pre-set exposure limits are exceeded. Thus, a worker would get feedback on exposure above that pre-set limit and on her/his daily dose at the end of the shift, both of which could assist in guiding personal protective equipment use.

Project Approach and Summary

In this project, research will evaluate the dosimeter using built-in feedback systems as an intervention method for preventing noise-induced hearing loss and will examine the relationship between noise levels and risk of acute occupational injury. Results will provide quantitative noise dosimetry, an assessment of the dosimeter as an intervention method and a potential leading indicator for noise-induced hearing loss and other injuries. By the end of the project, results should provide a method for assessing a state-of-the-art intervention method and an assessment of noise-induced hearing loss as a leading indicator for a number of acute workplace injuries.

Benefits

Workplace injuries are traditionally targeted using interventions proximal to the acute event, such as behavioral factors, rather than distal factors, such as other exposures. Furthermore, hearing loss is often attributed to workers’ lack of compliance, lack of supervision, or inappropriate use of personal protective equipment. This project assesses a potential leading indicator, not only of hearing loss, but also of workplace injuries. The developed intervention, if successfully applied, may result in reduced frequency of hearing loss and occurrence of acute injuries in the workforce, with associated potential cost savings and improved worker health and performance.

Occupational hygienists, managers, and safety specialists within electric utilities may use the in-ear dosimeter as a means to train their workers on the effective use of hearing protection and to clarify whether workplace noise is a contributor to other occupational injuries. Additional benefits derived from the work include an improved method to comply with OSHA “Employee Notification” requirements (1910.95).
Program Overview

Program Description

Power generators globally face chronic equipment problems in the more than 1,500 non-nuclear/non-hydroelectric generating units that are up to 30 years old or older, and new maintenance challenges are created by the addition of equipment to upgrade the performance and improve the emissions of these existing plants. In addition, new generation in the form of combined-cycle combustion turbines, biofuel boilers, and wind farms is adding to the need to develop guidance for new types of balance-of-plant (BOP) components.

Generators need to reduce maintenance-related O&M costs for aging equipment while improving equipment reliability, but are challenged by diminishing collective experience and knowledge and an urgent need to develop new maintenance and engineering staff as the current workforce retires. The training and knowledge that are needed to educate and inform new staff are not always readily available from vendors or equipment suppliers.

The Electric Power Research Institute’s (EPRI’s) Generation Maintenance Applications Center (GenMAC, formally FMAC) program (Program 104) provides practical information for improving plant maintenance-related operations and maintenance (O&M) processes, reliability, and cost through collaboration with participating organizations.

Research Value

EPRI’s Generation Operations and Maintenance programs develop advanced processes and related technologies that support improved plant reliability and reduced maintenance costs. The programs address the key tactical challenges facing plant owners relating to predictive maintenance, work management, conduct of operations, instrumentation, workforce, condition monitoring, and risk. These programs are highly collaborative in nature, providing forums for EPRI members to jointly resolve issues, improve processes, and identify research gaps. Members of the GenMAC program can use the R&D to:

- Improve reliability through guidelines that present the most current technology-based preventive and condition-based maintenance solutions
- Find faster solutions to day-to-day maintenance issues, following proven techniques and access to hotline support
- Develop strategies to resolve urgent problems, using guidelines developed according to member priorities
- Improve staff knowledge and competence through training that addresses industry-wide needs
- Develop better maintenance practices and reduce human error through the use of clear, easy-to-read guidelines, complete with precautions and tips for error avoidance
- Make improved maintenance guidance available for the next generation of electrical production equipment, added environmental systems, and balance-of-plant (BOP) components in newly designed power generating units.

Approach

Information is disseminated via maintenance guides, technical newsletters, hands-on workshops, user groups, Internet resources, and a toll-free technical support hotline. Gen-MAC works to resolve maintenance, equipment, and reliability problems using solutions that are shared.

- Technical maintenance guidelines address plant maintenance, including equipment, systems, and processes. A typical equipment guide will include equipment descriptions, failure modes, application information, troubleshooting, preventive maintenance tasks and basis, and training material for maintenance, operations, and engineering.
Accomplishments

EPRI's Generation Maintenance Applications Center program continues to develop maintenance guidelines and process guides that address new and continuing issues facing the industry on a daily basis. Using input from the members, data collected during plant visits, and feedback from various meetings, the program compiles a list of needed products that members prioritize each year, based on changing needs. R&D in this program has:

- Produced more than 100 maintenance applications guides and eight webcasts
- Supported seven component/issue user and interest groups that aid members’ staff development efforts
- Organized four workshops per year, directly related to components targeted for the highest impact in improving reliability
- Delivered technology improvements on current reliability problem areas via a webcast series
- Provided an annual electronic library with the past and current products for members who participate for three or more years
- Handled more than 100 hotline calls from members needing help to resolve plant problems, providing solutions or linking them to other members with similar experience

Current Year Activities

The program R&D for 2011 will focus on capital component reliability improvements and sustainability of gains already made through the use of the maintenance guidelines. The Generation Maintenance Applications Center plans to use primary communication pathways such as site visits and webcasts to assist members in learning how to best use the products and transfer EPRI technology to the various maintenance and operations practitioners at their facilities. Specific efforts will include:

- Member-selected component application guidelines developed each year as guided by member priorities.
- Member-selected training webcasts using EPRI products as primary content
- Site visits and mini-assessments of material condition at selected generating stations with a focus on EPRI products that can provide corrective action.

Estimated 2012 Program Funding

$1.2M

Program Manager

Ray Chambers, 704-595-2580, rchambers@epri.com
Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</table>
| P104.001       | Plant Equipment Maintenance Resources             | Program 104 develops technical guides, for direct use by maintenance, operations, and technical support organizations, that capture the experience-based knowledge of today's aging expert workers, and combine it with design and vendor knowledge to deliver ready-to-use equipment guidance for the overall improvement of component reliability and cost reduction. Members of Program 104 actively select projects for development each year so that each product is relevant to current issues. Examples of critical issues in order of importance as of early 2011 include:  
- Foreign material exclusion practices for fossil and training course material  
- Explosive dust control program and best practices, NFPA 654  
- Bag houses maintenance guideline  
- Selective catalytic reduction (SCR) system maintenance guidelines  
- Arc flash protective measures for fossil stations  
- Dry scrubber system maintenance guideline  
- Balance-of-plant (BOP) equipment guidelines for combined-cycle stations |
| P104.002       | Implementation of Plant Equipment Maintenance Resources | This project will provide;  
- Reports on best methods for implementation of Gen-MAC guidelines  
- Webcast training sessions on Gen-MAC products for member internal training  
- Hotline access to Gen-MAC staff to assist members in resolving equipment problems  
- Maintenance Center Memos, which provide quick references on “how-to’s” and use of products, and include schedules for users group meetings  
- Product listings for desk references of Gen-MAC products |

P104.001 Plant Equipment Maintenance Resources (100846)

Key Research Question

Aging generation facilities face rising costs as more equipment becomes obsolete and equipment suppliers focus on upgrades instead of repair options. Power stations also are losing experienced maintenance and engineering plant staffs, and have limited resources to develop new maintenance and engineering staffs. As a result, some stations have experienced serious day-to-day maintenance issues that require more complex repairs. In addition, most plants are installing new equipment to upgrade performance or control emissions, creating new maintenance challenges from significantly different equipment. New generation in the form of combined-cycle combustion turbines, biofuel boilers, and wind farms is adding to the need to develop guidance for new types of balance-of-plant (BOP) components.

Approach

Generation Maintenance Applications Center technical maintenance guidelines address component or equipment maintenance at a tactical level for both the technical staff and the maintenance technicians. A typical equipment guide includes equipment descriptions, failure modes, application information, troubleshooting, preventive and condition-based maintenance tasks, operator inspection tasks, and any special considerations for each component. This project will develop component guidelines that provide enhanced knowledge to help
stations develop a solid maintenance basis to justify how equipment is maintained and a training basis for the staff. The Preventive Maintenance Basis Database (PMBD) is supported by P104.001 through the development of a component's failure modes and effects and barriers to them. The PMBD is available to Gen-MAC members with three-year commitments. Information used to create the guide documents is applied to the PMBD to maximize overall reliability based on failure risk. Project focus will be on balance-of-plant equipment in generating facilities at non-nuclear and non-hydroelectric stations such as pulverized coal, combined-cycle, and combustion turbine facilities.

Impact

- Guidelines provide updated information on critical balance-of-plant (BOP) equipment.
- Guidelines are in standard formats and include the most current technology-based solutions in preventive and condition-based maintenance.
- Subsections in the guidelines provide basic and advanced knowledge to strengthen or provide staff training.
- The guideline contents can be exported to users' documents for inclusion of plant-specific information or into planning documents for maintenance instructions.
- Information is provided in a clear, consistent, easy-to-read manner, with precautions and advice to reduce human error.
- Material can be incorporated with little or no adjustments into training material, maintenance work packages, and company instructions.

How to Apply Results

More than 100 maintenance application guides currently are available for members to distribute internally throughout their systems. These guides function as reference material for job planning, equipment troubleshooting, and component performance monitoring. Members can use Program 104 webcasts of technology improvements on current reliability issues for plant-specific training, either for new hires or continuous improvement. Program 104 supports four component/issue user and interest groups and four workshops per year, focused on fossil components that can have the greatest impact on improving the reliability of plant equipment. Hotline calls help members resolve plant problems by providing solution suggestions or by linking them to other members with similar experience.

2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Technical Guides on Member-Selected Subjects:</strong> Technical guides based on current member-selected topics will address the latest member needs in plant maintenance, including plant equipment, systems, and component reliability processes. Topics suggested in recent surveys and meetings will be combined and refined through member oversight. Surveys completed in 2011 suggested development of best practices and maintenance guidelines addressing issues such as explosive dust control equipment best practices; arc flash protective measures best practices; aging cable management practices; underground piping maintenance guidelines; expansion joint maintenance guidelines; industrial safety improvement techniques for mechanical and electrical component repairs; pipe hanger maintenance guidelines; maintenance guidelines for bag houses; ash pond/impoundment maintenance guidelines and best practices; dry ash storage system maintenance; and component/system winterization guidelines.</td>
<td>12/30/12</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>
PMBD Equipment Data Tables: The Plant Maintenance Basis Database Data Tables are developed as a part of the maintenance guideline development process. Based on member-selected needs, data tables will be developed for new guidelines or pre-existing guidelines. Once developed and uploaded, they are available immediately to members using the Plant Maintenance Basis Database tool. This becomes a resource for balancing the amount of labor and material resources used by their preventive maintenance (PM), predictive maintenance (PdM), and Operations rounds processes to achieve a desired level of reliability.

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<td>PMBD Equipment Data Tables: The Plant Maintenance Basis Database Data Tables are developed as a part of the maintenance guideline development process. Based on member-selected needs, data tables will be developed for new guidelines or pre-existing guidelines. Once developed and uploaded, they are available immediately to members using the Plant Maintenance Basis Database tool. This becomes a resource for balancing the amount of labor and material resources used by their preventive maintenance (PM), predictive maintenance (PdM), and Operations rounds processes to achieve a desired level of reliability.</td>
<td>12/28/12</td>
<td>Technical Resource</td>
</tr>
</tbody>
</table>

P104.002 Implementation of Plant Equipment Maintenance Resources (070557)

Key Research Question

Facilities that seek to use Program 104 products need to quickly become proficient if they are to recognize cost savings and reliability improvements. Power stations are losing experienced maintenance and engineering plant staffs, and have limited resources to develop new maintenance and engineering staffs. They need to use the products and services in this program to support the development of replacement personnel, as well as integrate the program’s knowledge base in their internal organizations. As they work on installing new equipment to upgrade performance or control emissions, they are creating new maintenance challenges for an aging staff /or young, inexperienced staff. The challenges of maintaining stations with newer staff personnel will require significant training and self-study.

Approach

Members want to achieve maximum value as soon as possible and are seeking the best methods to achieve full implementation of the Generation Maintenance Applications Center (GenMAC) products. GenMAC provides assistance in implementation of technical guidelines to address component or equipment maintenance at a tactical level. This assistance is provided through our proven media:

- Workshops
- Users and interest groups
- Maintenance Center Memo
- Newsletters
- Webcasts for informational needs, training on GenMAC products, and training on EPRI products that are available to the general public and address member needs.

Equipment guides typically include equipment descriptions, failure modes, application issues, troubleshooting tips, repetitive tasks, and operator inspection tasks, which should be used to achieve highly reliable equipment performance. Users often find themselves in need of assistance in implementation and seek best methods. The project focus will be on balance-of-plant equipment within generating facilities at non-nuclear and non-hydroelectric stations such as pulverized coal, combinedcycle, and combustion turbine facilities.

Impact

- Training on use and implementation of guidelines that provide updated information on critical balance-of-plant (BOP) equipment
- Basic and advanced knowledge to strengthen or provide staff training
- Guideline contents capable of export to users' documents for inclusion of plant-specific information or into planning documents for maintenance instructions
• Information provided in a clear, consistent, easy-to-read manner, with precautions and advice to reduce human error
• Regularly scheduled training and informational webcasts
• Hotline access to industry experts

How to Apply Results

Members achieve value from this project by participating in sponsored user groups, workshops, the EPRI Plant Manager Forum, webcasts, and training sessions. Members are encouraged to establish routine training for staff members with the EPRI Program 104 training webcasts. Use of the guideline implementation best practices can ensure the maximum opportunity to expose the maintenance organization to the EPRI products. Actively maintaining a matrix of staff members assigned to the various interest group and contact points in Program 104 maximizes the value of program results.

2012 Products

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<tbody>
<tr>
<td><strong>Member-Identified Technical Workshops</strong>: Workshops on topics of need are identified by members annually through surveys, meetings, and conferences. The workshops are delivered by classroom, conference, and distance learning techniques, including training webcasts.</td>
<td>12/28/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Computer-Based Training: Equipment Reliability Module (Member-Identified Topic)</strong>: Computer Based Training Modules are developed annually based on existing P104 guides, with the focus on training plant staff on proper maintenance and repair techniques</td>
<td>12/28/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Fossil Pump Users Group</strong>: The Fossil Pump Users Group is geared toward engineering and maintenance personnel involved in pump maintenance, testing, troubleshooting, and performance. Attendees can benefit from interaction with other plant utility personnel and recognized industry experts through the technical presentations/discussions.</td>
<td>12/28/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Pulverizer Interest Group</strong>: The Pulverizer Interest Group is geared toward engineering and maintenance personnel involved in pulverizer maintenance, testing, troubleshooting, and repair. Attendees can benefit from interaction with other plant utility personnel and recognized industry experts through the technical presentations/discussions over a series of webcasts.</td>
<td>12/28/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>FGD Equipment Reliability Interest Group</strong>: The FGD Equipment Reliability Interest Group is geared toward engineering and maintenance personnel involved in flue gas desulfurization (FGD) equipment maintenance, testing, troubleshooting, and repair. Participants can benefit from interaction with other plant utility personnel and recognized industry experts through the technical presentations/discussions and participation on technical advisory committees that address specific equipment reliability challenges with FGD equipment.</td>
<td>12/28/12</td>
<td>Technical Resource</td>
</tr>
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</table>
| **Coordinated Equipment User and Interest Groups**: Six equipment user and interest groups are accessed through the Generation Maintenance Application Center in coordination with other EPRI programs. Reduced attendance fees are provided for GenMAC-sponsored programs:  
  • Fossil Plant Managers Forum (sponsored by GenMAC and O&M Area Programs)  
  • Transformer and Switchyard Users Group (sponsored by GenMAC and EPRI’s Nuclear Sector)  
  • Rigging and Lifting Users Group (sponsored by GenMAC, and the Nuclear Sector)  
  • Large Motor Users Group (sponsored by GenMAC, and the Nuclear Sector)  
  • Breaker Users Group (sponsored by the Nuclear Sector)  
  • Relief Valve User Group (sponsored by the Nuclear Sector) | 12/28/12 | Technical Resource |
Supplemental Projects

Combustion Turbine and Combined-Cycle Maintenance Basis (071983)

Background, Objectives, and New Learnings

The objective of this project is to develop a maintenance basis for combustion turbines (CTs), combined-cycle stations, and co-generation plants using CTs. A maintenance basis provides a rationale to determine critical or important generation components and identify the most effective tasks to address reliability, cycling operation, and forecasting of remaining life. A comprehensive maintenance basis ensures that overhauls are scheduled and unanticipated breakdowns do not occur. As a result, generation assets will provide a more reliable and cost-effective generation resource for the public’s benefit.

The changing power market, with increasing emission regulations and favorable projected natural gas prices, is resulting in increased capacity factors of existing combustion-turbine combined-cycle (CTCC) plants and the addition of new CTCC plants. The increasing reliance on these assets to support more baseload capacity drives the need for comprehensive O&M strategies in maintaining these assets.

Project Approach and Summary

Components that are important to long-term generation reliability and high-cost capital components will be identified and analyzed using proven techniques. From this list of critical components, EPRI, project participants, and equipment experts will determine through collaboration what types of failure modes exist and will identify the most effective tasks with a focus on condition-based maintenance (CBM). CBM is a proven lowest-cost approach to failure avoidance and results in the best use of the total mission time of components.

The collaborative equipment failure analysis for each component type will include three major outputs:

- **Templates** are ready-made, equipment-specific maintenance regimes for various operational modes that include CBM, time-based maintenance, and operational observation. Users can quickly deploy templates in their maintenance programs.
- **Equipment data tables** allow project participants to adjust templates, utilizing EPRI’s Vulnerability method to further optimize their own maintenance basis with confidence.
- **Maintenance guidelines** provide project participants a reference that can be used by company O&M craft or contract maintenance, or when developing a specification for a third-party service organization.

EPRI will facilitate a combination of site visits, on-line meetings, and live workshops to aid in collaboratively developing model maintenance programs.

Benefits

Users will be able to assemble a plant maintenance basis that reflects their actual operational plan for the station, instead of a single maintenance strategy that could lead to excessive overhauls of equipment with limited wear. The component maintenance guidelines and associated maintenance basis templates developed by this project will allow a more flexible approach to the selection of equipment monitoring and maintenance resources for critical components.

Project participants can choose from a variety of maintenance resources and strategies that are identified by the templates, with a risk evaluation associated with each task. This project will upgrade EPRI’s Plant Maintenance Basis Database (PMBD) failure tables, adding specific CTCC data and creating a more complete tool for the power generation industry.
Operations Management & Technology - Program 108

Program Overview

Program Description

Operations performance in today’s fossil generation plants is the key to achieving highly reliable, safe, economic, and environmentally compliant plant performance. The operations staff and management provide the human performance that controls the operation, directs and performs equipment condition monitoring, and performs predictive and corrective maintenance activities. Also playing a significant role in the overall plant performance are work processes, clear goals and objectives, personnel development, communication, support facilities, and plant design. Effective integration of wide-ranging skills and knowledge, work processes, and design — along with strong leadership by the management team — are critical to plant success.

The Electric Power Research Institute’s (EPRI’s) Operations Management & Technology program (Program 108) provides a forum for the development and evaluation of new and improved fossil plant operations technologies, work policies, and practices that raise standards of operational performance.

Research Value

EPRI’s Operations Management & Technology program develops advanced processes and related technologies that support improved plant reliability and reduced costs. The program addresses the key tactical challenges facing fossil plant owners relating to management, conduct of operations, workforce performance, equipment monitoring, and risk. This program is highly collaborative in nature, providing forums for EPRI members to jointly resolve issues, improve processes, and identify research gaps. Members of the program receive:

- Guidelines that provide tools for excellence in plant operations
- Forum for industry information exchange
- Improved plant operations through support from EPRI technical staff
- Opportunities for enhanced plant operations through understanding of new technology applications

Approach

This program helps operating crews apply industry best practices and understand new technologies, and understand the ways that both can be applied to plant operations to identify vulnerabilities, manage risk, and exchange information with peers.

- R&D of plant operations fundamentals and new developments provides guidance to plant operators and their managers on best practices in fossil plants through exchanges of ideas and shared lessons on improved operational performance and new technologies.

Accomplishments

EPRI’s Operations Management and Technology program has helped members through implementation of products to assess operations performance, improve operations processes, learn from industry experiences, and exchange ideas with industry peers. Products have included:

- Updated Operations Assessment Guideline, which helps members understand their strengths and areas for improvement in operations. The guideline is updated based on members’ experiences.
- Annual operations conferences, which allow industry peers from shift operations to share experiences, problems, and solutions
- Lessons learned from industry events, which provide information about prevention of similar events at other facilities
- Guideline on managing emergency events
- Guideline on clearance and tagging
Guideline on alarm management
Evaluation of high-performance human-machine interface (HMI) control displays

Current Year Activities
The program R&D for 2012 will continue to develop guidelines that support excellence in fossil operations, sharing of lessons learned from industry case histories, reviewing technology applications, and fostering information exchange among the membership. Specific efforts will include:

- Annual operations and future operations perspectives conference
- Case history database maintained to summarize events shared by members
- Technical support of members
- Conduct-of-operations guideline on topic selected by advisors
- Developing distributed control system (DCS) specifications to assist in operating logs and routine data requirements
- Understanding of new North American Electric Reliability Corporation (NERC) requirements' impact on plant operations
- Results from operations assessment activities

Estimated 2012 Program Funding
$1.0M

Program Manager
Wayne Crawford, 704-595-2727, wcrawford@epri.com

Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P108.001</td>
<td>Plant Operations Fundamentals and New Developments</td>
<td>This project provides guidance on industry best practices for plant operations, evaluates technology applications, and supports information exchange among members to foster continuous improvement of fossil plant operations.</td>
</tr>
</tbody>
</table>

P108.001 Plant Operations Fundamentals and New Developments (067361)

Key Research Question
Clear descriptions of best-practice performance and benefits of new technologies for operations are needed to support industrywide improvement efforts. Plant operations staffs need effective information sharing to learn from the experiences of others.

Approach
This project provides the ability to exchange information among members and develops guidance to improve plant operations activities. Information exchange is facilitated through an annual conference. EPRI staff provides technical support, which often includes input from other members. A full set of Conduct of Operations Guidance is being developed to capture the best operational performance practices and provide detailed information on the conduct of operations, based on member rankings of importance. Reports on new technology developments offer insight into application successes and problems. Supplemental projects assist members with product applications when required.
Impact

- Improved plant operations result in lower cost and increased generation.
- Plants can avoid negative events by studying industry experiences and taking preemptive corrective action.
- Savings and performance improvements are gained by learning from others’ experiences to effectively implement new technologies.
- Fewer operator errors and improved response to events reduce impact on plant equipment, prevent outages, and result in increased production.

How to Apply Results

Plant operations staffs compare their existing practices with those reported in guidelines to determine areas that can be improved through new or revised procedures, instructions, training, and management coaching. Lessons learned through event reviews or operations conferences are evaluated in the plant to determine if changes to operational practices are required. New technologies applied using ideas from EPRI guidance or industry experience can achieve maximum value with minimum impact on plant staff.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td><strong>DCS Specifications for Operating Logs and Data Requirements</strong>: Generic specifications for distributed control system (DCS) functionality to support plant operators in maintaining logs of actions and collecting and formatting data typically required by plant operators. Numerous demands are placed on operators to create routine reports of plant data; having this capability built into the DCS will alleviate the operator of non-productive tasks and increase data accuracy and timeliness. Members can use the specification to work with DCS suppliers to create enhancements that can greatly improve operator log quality, accuracy, and ease of creating and maintaining log sheets. The following topics are expected to be addressed:</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>- Review of best practices for managing operating data, requirements for data collection, storage, and analysis such as heat rate, inventory management, equipment performance data (base line and routine)</td>
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<tr>
<td>- Creation of reports required for management review</td>
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<tr>
<td>- Logs — all operator actions logged with added fields for operator discussion such as equipment starts, controls changes, manual stops, auto/manual station changes</td>
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<td>- Pull-down menus to reduce typing requirements, based on plant experience</td>
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<tr>
<td>- Inputs to turnover checklists</td>
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<tr>
<td>- Daily management reports</td>
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<tr>
<td>Auto/reminders to email to key plant staff</td>
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</tbody>
</table>
Product Title & Description | Planned Completion Date | Product Type
--- | --- | ---
**Impact of New NERC Standards on Plant Operations:** New North American Electric Reliability Corporation (NERC) standards are being promulgated with plant operators from different companies making individual interpretations and devising actions to meet the new requirements. Guidance is needed to assist plant operators in understanding the requirements and how they can be effectively implemented to achieve full compliance. Plants also need support in preparing to be audited and to demonstrate compliance. This project should include:
- Review of new NERC standards and identification of impacts on plant operators
- Summary of impacts, potential changes, or requirements that should be addressed by each plant operating staff
- Methods that have been or could be used to achieve compliance with minimal impact on daily operations
- Review of NERC audits to provide guidance on audit preparation

**Database of Plant Case History Reports:** Members provide event descriptions that are summarized and included in a shared online database. As members report events, they are summarized as anonymous reports. Members can access the database to learn of new events and lessons learned by their peers in the industry. Effective utilization of experiences of others has been a significant contributor to improved performance in the U.S. nuclear industry and offers similar opportunities for fossil plant operators. The existing database contains events from the last three years and will continue to expand as members share their experiences.

**Conduct of Operations Topic Selected by Advisors:** Advisors annually select a topic in a continuing series of Conduct of Operation topics. Previous topics have included operator rounds, shift turnover, emergency management, control of operational aides, and communication standards. Some topics remaining to be described include housekeeping, procedures guideline, material condition assessments, managing complex and coordinated activities, control room performance, equipment monitoring, and equipment labeling. This project is a multiyear effort to describe in detail all basic elements of a complete Conduct of Operations Guideline.

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**Future Year Products**

Product Title & Description | Planned Completion Date | Product Type
--- | --- | ---
**DCS/Operating Procedure Integration Specification:** Describes the concepts of integrating procedures into DCS systems. Key procedures such as unit or major component startups and shutdowns can be included into the DCS, with links to data and plant conditions that aid the operator in the effective implementation of the procedure. Some ideas to be considered are:
- Develop specifications for having procedures to guide significant operations actions included in the DCS
- Specifications to include prerequisite/condition status per procedure
- DCS to document operator actions per procedure, operator sign off of checklist
- DCS to confirm equipment response per procedure, independent instrumentation to confirm response
<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Future Perspectives in Operations:</strong> This report will investigate the leading indicators that will affect the future for plant operators, including drivers and trends understood today. New trends and technologies affect how plants will be operated in the future; some of the topics of interest include:</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td>• New plants and major modifications to existing plants are changing the landscape for operators</td>
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<td>• Advances in control systems will change the way operators interface with the plant</td>
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<tr>
<td>• Remote and contracted operations should be investigated</td>
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<tr>
<td>• Industry trends and operations-related developments reviews</td>
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<tr>
<td>• Member needs and interests in new technology, operational concepts, and objectives</td>
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<tr>
<td><strong>Design-Limited Operations:</strong> Design requirements for existing plants have been modified many times over the life of the plant. As plants continue to operate with both old and newly modified equipment, creating effective operating limits linked to design is important for the safe and reliable operation of the units. This project will provide data on:</td>
<td>12/31/14</td>
<td>Technical Report</td>
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<tr>
<td>• Controls for exceeding design</td>
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<tr>
<td>• Establishing maximum dependable capability</td>
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<tr>
<td>• Ramp rates</td>
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<td>• Instrumentation requirements, critical parameter monitoring</td>
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<td><strong>Operations Metrics:</strong> A compilation of operations metrics, definitions, and perspective on what is being measured, including:</td>
<td>12/31/14</td>
<td>Technical Update</td>
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<tr>
<td>• Limitations of key metrics</td>
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<tr>
<td>• Broad base for member selection, enabling users to pick metrics that link to business plans and corporate goals</td>
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<tr>
<td>This report is not expected to drive industry standardization, but offer individual member insights.</td>
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<tr>
<td><strong>Methodology for investigation of events for DCS improvements:</strong> Current event investigations do not include evaluation of DCS operator graphics displays as a source for preventing or mitigating future events. Guidance on performing these type reviews could include</td>
<td>12/14/15</td>
<td>Technical Update</td>
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<tr>
<td>• Links to CAP guidelines as appropriate</td>
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<tr>
<td>• Consideration of both alarms and DCS graphics as areas for improvements</td>
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<tr>
<td>• Examples from actual industry events</td>
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<tr>
<td>• Investigation of combinations or other precursors as &quot;smart alarms&quot;</td>
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<tr>
<td><strong>Operations Outage Management:</strong> Operations performance is key to effective outage accomplishment. EPRI intends to document best practices being implemented to achieve better operations support of outage work. Some of the topics that should be addressed are:</td>
<td>12/31/15</td>
<td>Technical Update</td>
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<tr>
<td>• Tag-out organization and implementation for optimum outage performance</td>
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<td>• Use of overtime and additional resources for critical work demands</td>
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<td>• Post-maintenance and post-modification acceptance testing</td>
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<td>• On-line versus outage determinations</td>
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<tr>
<td>• Shutdown and startup scheduling and optimization</td>
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<tr>
<td>Product Title &amp; Description</td>
<td>Planned Completion Date</td>
<td>Product Type</td>
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<tr>
<td><strong>Electronic Equipment Labeling, RFID and Other Technologies:</strong> Accurate labeling of</td>
<td>12/31/16</td>
<td>Technical Update</td>
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<tr>
<td>plant equipment is key to reducing human error by operations and maintenance personnel.</td>
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<tr>
<td>Several technologies are currently being used to help ensure the correct component is</td>
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<td>being operated or maintained by plant staff. To assist members who are considering</td>
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<td>making improvements in plant labeling, the report should include:</td>
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<tr>
<td>• Overview of technologies</td>
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<td>• Application to fossil plants</td>
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<tr>
<td>• Member experiences in new labeling technologies</td>
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<tr>
<td>• Labeling electronic links to other work processes, clearance and tagging, and rounds</td>
<td></td>
<td></td>
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<tr>
<td>data</td>
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<tr>
<td><strong>Configuration Management:</strong> Fundamentals of an effective Configuration Management</td>
<td>12/31/16</td>
<td>Technical Report</td>
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<tr>
<td>Program are important to be understood and implemented. Plants being operated with</td>
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<tr>
<td>undocumented changes, outdated drawings, and unanalyzed design changes create</td>
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<td>unnecessary hazards to the equipment and staff. A report should include:</td>
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<tr>
<td>• Member experiences in Configuration Management</td>
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<tr>
<td>• Building the case for a comprehensive program</td>
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<tr>
<td>• Transition from existing disperse information to integrated, user-friendly data</td>
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<td>• Design basis</td>
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<td>• Major modifications, taking advantage of these additions and data management</td>
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</table>
Supplemental Projects

Fossil Plant Operators Situational Awareness Enhancements (071259)

Background, Objectives, and New Learnings

Like other complex operations, power plants depend on human oversight to keep physical processes performing according to design and prevent equipment and systems from failing. A key element of operators' control of power stations can be summed up by the term “situational awareness.” Operators have been trained to respond to routine and off-normal situations; however, to correctly respond, they must fully understand the numerous variable conditions so that appropriate, effective actions can be taken. Full understanding of conditions — i.e., situational awareness — is paramount to guide operator decisions and actions during routine equipment malfunctions and natural events such as tornados, hurricanes, or floods.

For a variety of reasons, current alarm systems — those that warn the operator of off-normal conditions — are not effective in providing plant operators with clear, actionable warnings, challenging their ability to retain overall situational awareness. Operators often are flooded with unimportant alarms, leaving them unable to identify the few valuable alarm conditions. In other cases, alarms are generated unnecessarily, creating similar distractions to operators.

Industry studies have shown that operators can effectively manage 150 alarms per day, and likely cannot effectively manage systems that generate more than 300 alarms per day. Many of the alarm systems in power plants today create more than 1,000 alarms per day and are distracting operators, reducing their situational awareness, and increasing the likelihood of equipment damage (as has been experienced at some plants) and accidents.

The objective of this project is to demonstrate the practical implementation of research work competed by EPRI, which is intended to improve operator situational awareness and overall control of equipment and the electrical generating process. Insights gained by implementing the EPRI-developed guidelines at multiple units and multiple companies generating plants will validate concepts that could be applied widely across generating units. These key insights include both the challenges associated with guideline implementation as well as the benefits. Under differing operating and design conditions experienced by members, evaluation of alarm system improvements can be accomplished with direct correlation to operator situation awareness improvements.

Project Approach and Summary

This project uses specifically designed software and technical guidance to support members in reducing distracting alarms, which affect unit operators' abilities to manage normal, abnormal, and emergency situations. Plant operators, control technicians, engineering staff, and component experts from the site form a team, led by a facilitator, to review each alarm against an alarm philosophy reference document to eliminate unnecessary alarms, establish correct priority, confirm set-points, and guide operator responses to off-normal conditions.

Host sites evaluate plant alarms for those that effectively support operational needs. Correct alarm priorities are established, and actions identified to resolve nuisance or troublesome alarms. A data base for each plant alarm is developed for reference by plant operators.

Benefits

Host sites can gain much greater understanding of their alarm system conditions and can conduct a structured review of all alarms to understand the distributed control systems (DCS) changes needed to achieve a manageable, nondistracting level of alarm activity. Operators can achieve a higher degree of situational awareness that will support more effective operation.
Self Assessment and a Culture of Continuous Improvement in Fossil Generating Stations (066048)

Background, Objectives, and New Learnings

Generating facilities today are seeking to improve O&M performance and create lower cost, more reliable, and safe electricity with minimal impact on the environment. To achieve these goals, it is necessary to understand where improvements can be achieved and what barriers must be overcome to sustain continuous improvement.

These improvements, collectively, could result in more reliable generating facilities, fewer environmental emissions, and fewer events that challenge health and safety. EPRI is fostering the concept of self-assessment, along with a culture of continuous improvement, within the industry to achieve improved performance. To that end, EPRI has updated industry guidance as reported in *Updated Operations Assessment Guideline* (EPRI report number 1014200).

The objective of this project is to obtain knowledge of barriers that affect continuous improvement in O&M practices at generating stations. Through application of the EPRI Guideline at host sites, EPRI staff, along with member host sites and peers from other members plants, are validating the guidance and gaining insights into barriers that affect continuous improvement.

Project Approach and Summary

Performance-based assessments are performed at host sites, using site peers and staff from other host companies' sites. Team members and plant staff are trained in assessment methods. Peers learn from the EPRI team and assessment performance steps and techniques.

Benefits

Host site staffs benefit from participation on assessment teams and by learning assessment concepts. Sites receive assessment results, identifying areas for improvement and strengths in performance. The industry gains assessment experience through peer participation in assessment activities.
Renewable Generation - Program 84

Program Overview

Program Description
Renewable energy is fundamentally changing the electricity industry's strategic landscape. Active industry engagement in development and deployment of renewable energy for power generation has increased significantly, and continued engagement is more critical than ever before. Renewable portfolio standards, financial incentives, concerns over energy security, and efforts to reduce greenhouse gas emissions will continue to drive renewable energy deployment. Over the long term, renewable energy investment will depend on renewables operating cost-effectively without mandates or subsidies. Research and development can improve the efficiency of various technologies in converting renewable energy resources to electricity. Improved operations and maintenance practices and technologies can reduce costs associated with utility-scale operations of renewable power plants. Up-to-date information is critical to explore new opportunities for deployment, operation, and maintenance of renewable generation. Finally, targeted research and large-scale demonstrations are necessary to reduce the cost of renewable generation, improve overall reliability, and facilitate widespread deployment.

The Electric Power Research Institute’s Renewable Generation program (Program 84) provides a robust portfolio of research and development opportunities that:

- Assesses the status, performance, and cost of renewable generating technologies;
- Evaluates policy scenarios and how they may affect the future mix of renewable generation technologies;
- Conducts targeted research and development to address critical issues relative to the technical assessment, selection, operation, maintenance, and overall reliability of renewable generation resources, and
- Provides opportunities for members to engage in general-interest renewable generation activities, including workshops, tours, and other events.

Research Value
Renewable energy resources and their application in generating electricity most often are considered collectively when addressing key drivers in renewable energy deployment, including renewable portfolio standards, energy security, greenhouse gas emission reductions, and other issues. However, wind, solar photovoltaic, solar thermal, biomass, and geothermal energy options largely are unrelated technologically; each has its own developmental status, readiness timeline, and economic and technology challenges. EPRI's Renewable Generation program conducts targeted research to improve the performance, availability, and cost-effectiveness of existing renewables technologies and to develop new renewable technologies and applications. EPRI's Renewable Generation program also provides objective cost and performance information for renewable technologies, helping participants to:

- Capitalize on market opportunities for renewable compliance and power purchases, resulting in improved decision-making;
- Identify the appropriate role of diverse renewable resources in expanding new and sustainable generation capacity; and
- Apply results from modeling, simulation, and future energy scenario analyses that will help guide investments in renewable energy.

Through collaboration with key industry stakeholders, EPRI members guide development and demonstration of technologies that will optimize operating efficiency, reduce overall costs, and facilitate deployment of large-scale renewable generation.
Approach

Value is delivered to members of Program 84 in a variety of ways:

- EPRI keeps members informed on global technical developments through advisory meetings, webcasts, and networking to share experiences and capitalize on the lessons learned by others.
- Participants are able to identify and prioritize research needs and engage in technology-specific research and development projects that focus on specific areas of interest. Participants benefit from the collaborative development of solutions to common technology challenges that they could not afford to solve individually.
- Through collaboration with technical experts across EPRI (e.g., the Energy Technology Assessment Center, Waterpower Program, renewable integration, and energy storage activities), Program 84 helps members learn about the latest technologies to improve energy recovery from renewable resources, understand the role of these energy resources, and help develop and implement a robust research portfolio to address identified critical technology issues.
- Transfer of technology to participants is achieved through the generation of technical reports and guidelines, participation in technology development activities, pilot-scale demonstrations and testing programs, and technology applications at participant asset locations.
- Technology interest groups, topical workshops, and industry tours also are provided.

Accomplishments

- The Renewable Energy Technology Guide provides unbiased and up-to-date information on renewable energy status, performance, cost, installed capacity, and markets. It includes technology status information on renewable generation sources, including solar photovoltaic, solar thermal, wind, biomass, geothermal, and wave and tidal hydrokinetic resources. Grid integration technologies and greenhouse gas emissions control also are covered.
- Modeling and analyses efforts examine the role of renewables under different environmental and climate policies, evaluate the effects of federal and state renewable portfolio standards (RPS), and explore other possible future energy scenarios. Results support strategic planning for renewable portfolio standards and analysis of CO₂ emissions costs and related constraints. Products include economic and energy scenario analyses and topical reports on renewable technology issues.
- Program 84 R&D has led to enhanced understanding of the effects that increased percentages of biomass co-firing may have on combustion, emissions, emission control equipment, and overall plant operation. Ground-breaking research in biomass pretreatment (e.g., torrefaction) can lead to large-scale pilot testing of technologies that may allow for significantly increased biomass co-firing percentages.
- EPRI continues to perform leading studies in solar energy augmentation of existing gas and coal plants. Solar-augmented steam cycle collaborative projects identified options for utility-scale solar power generation without the significant challenges of siting a new plant and developing a new power block.
- Targeted research and development projects and field evaluations across renewable resources help improve the reliability and performance of renewable generation and provide guidance for improved operations and maintenance.
- General-interest activities in renewable generation technologies, including industry meetings, technical tours, and technology summits/workshops, provide valuable overviews of critical technology issues and help identify future research needs.

Current Year Activities

The Renewable Generation program in 2012 will continue to deliver cost and performance information to allow comparisons and better define the role of renewable generation among all generation options. Technology-specific opportunities for collaborative R&D will continue in 2012, enabling participants to engage in targeted R&D in individual renewable technologies of interest. The 2012 plan also includes technical forums, conferences, site visits, and workshops on topics of common interest, allowing participants to pool their R&D investments to develop solutions to common technology challenges. Through collaboration with technical experts across EPRI (e.g., the Energy Technology Assessment Center, Waterpower Program, renewable integration, and energy storage activities), members will learn about the latest technologies to improve energy
recovery from renewable resources, understand the role of these energy resources, and help develop and implement a robust research portfolio to address identified critical technology issues.

**Estimated 2012 Program Funding**

$6.0M

**Program Manager**

Stan Rosinski, 704-595-2621, srosinski@epri.com

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**Summary of Projects**

**PS84A Renewable Energy Economics and Technology Status (069178)**

**Project Set Description**

This project set provides basic information on the cost, performance, and status of all renewable technologies. Electricity sector analyses help better define the role of renewable generation and enable members to better understand policy implications on future generation options. This project set will deliver the Renewable Energy Technology Guide, detailed engineering and economic analyses of selected renewable technologies, perspectives on current topics, industry tours, presentations from industry experts, and forums for participants to exchange information. Periodic newsletters on the status of P84 activities and topical white papers also will be developed.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>P84.001</td>
<td>Renewable Energy Technology Guide and Updates</td>
<td>The information generated by this project will address the need for timely, objective, and consistent data on the status, performance, and cost of renewable technologies and their likely penetration over time.</td>
</tr>
<tr>
<td>P84.002</td>
<td>Renewable Engineering and Economic Evaluations</td>
<td>This project provides updated cost and performance for selected renewable technologies based on changes or improvements in design or deployment as well as variation in renewable resources.</td>
</tr>
<tr>
<td>P84.003</td>
<td>Renewable Energy Analysis and Strategy</td>
<td>The analysis and strategy project provides strategic information on current renewable technology issues, and modeling and analysis to better define the role of renewable energy in future generation portfolios.</td>
</tr>
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</table>

**P84.001 Renewable Energy Technology Guide and Updates (065781)**

**Key Research Question**

The principal drivers for renewable generation include government-mandated production goals, customer preferences, and environmental regulations. Examples of these are RPS, system benefit charges, net metering laws in the United States, and the goal in Europe of up to a 32% future share of renewables in overall electricity generation. It is increasingly important for energy providers to have the best available information about cost and performance of renewable generation options.

**Approach**

This project provides technology status, installation history, and performance cost information for a range of renewable energy technologies. Project activities include production of the annual edition of the EPRI Renewable Energy Technology Guide in electronic format; an eMedia renewable technology newsletter; and perspective reports that address market, regulatory, and other renewable energy issues.
Impact

- Conduct effective resource planning, avoid deployment mistakes, capitalize on market opportunities, lower O&M costs, and improve plant availability.
- Maintain a balanced generation portfolio that includes effective maintenance and reliable operation.

How to Apply Results

This project will provide annual updates of the Renewable Energy Technology Guide, periodic newsletters, and perspective report(s) addressing markets, regulatory impacts, and deployment over time. Members can use the energy information and data to:

- Assess the status and potential of renewable generation technologies
- Forecast the penetration of renewable energy into the generation portfolio mix for a range of scenarios, and
- Estimate the incremental impacts of adding renewable generation on fuel requirements, capital and O&M costs, and greenhouse and other pollutant emissions.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable Energy Technology Guide - 2012:</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>

P84.002 Renewable Engineering and Economic Evaluations (065782)

Key Research Question

All utilities face the question of exactly how renewable energy will fit in their future low-carbon and diversified choices for electricity generation. There is a significant level of business and technical uncertainty as to which emerging renewable technologies will be most cost-effective, reliable, and durable in the long term. Utilities need a clearer understanding of the opportunities and risks of relying on renewable generation and how this likely will affect the bottom line. It is increasingly important for energy providers to have the best available information about cost and performance of renewable generation options for use in corporate planning and strategy.

Approach

This project melds current engineering and economic evaluations with recent deployment cost experiences. The evaluations periodically are updated for a range of renewable energy technologies and will use consistent bases for cost and performance estimates to ensure the resulting data are consistent between technologies. In addition, each evaluation will address local renewable resource properties and cost indices for different sites in the United States and the world to allow the cost and performance estimates to be generated for site-specific applications. Two renewable technologies are targeted for evaluation each year, and they will be chosen in collaboration with members.

Impact

Up-to-date cost and performance data can make it possible to accurately assess the potential for renewable energy in future generation portfolios.
How to Apply Results

Members can use the renewable energy information and data to assess the status and potential of renewable generation technologies for site-specific conditions.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td>Engineering and Economic Evaluation of Renewable Technology 3: Each engineering and economic evaluation updates the status, performance, cost, and prospects for future improvement of a renewable energy technology, chosen in collaboration with members. The scope of the evaluations includes design and economic assumptions; conceptual design descriptions; raw material requirements, material and energy balances, and environmental emissions where applicable; and capital, O&amp;M, and levelized cost of electricity estimates. The cost estimates will be prepared for several specific locations, representing a range of renewable resource properties, material and labor cost indices, and labor productivities. Probability distributions will be generated for capital, O&amp;M, and levelized cost of electricity to indicate the range of uncertainty of the estimates.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Engineering and Economic Evaluation of Renewable Technology 4: Each engineering and economic evaluation updates the status, performance, cost, and prospects for future improvement of a renewable energy technology, chosen in collaboration with members. The scope of the evaluations includes design and economic assumptions; conceptual design descriptions; raw material requirements, material and energy balances, and environmental emissions where applicable; and capital, O&amp;M, and levelized cost of electricity estimates. The cost estimates will be prepared for several specific locations, representing a range of renewable resource properties, material and labor cost indices, and labor productivities. Probability distributions will be generated for capital, O&amp;M, and levelized cost of electricity to indicate the range of uncertainty of the estimates.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P84.003 Renewable Energy Analysis and Strategy (069179)

Key Research Question

Utilities face the question of how renewable energy will fit in their future low-carbon and diversified choices for electricity generation. There is a significant level of business and technical uncertainty as to which emerging renewable technologies will be most cost-effective, reliable, and durable in the long run. Utilities need a clearer understanding of the opportunities and risks of relying on renewable generation and how this likely will affect the bottom line.

Approach

This activity will build on existing modeling and planning tools, such as the National Energy Modeling System (NEMS) and the EPRI's Regional Economy, GHG, and Energy (REGEN) model, to address utility industry issues. Assumptions and future scenarios developed under this activity will include associated uncertainty and risk factors. Test simulations will be run, and model results will be tested and analyzed. The tools and strategies will be used to develop modeling and simulation results and delivered via presentations, webcasts, technical updates, and reports showing how generation options, resources availability, as well as proposed or current policies may affect the electricity sector, including specific regions of the United States.
Impact
- Results provide a comparison of how different policies, fuel prices, CO₂ costs, and technology advancement scenarios can affect the electricity sector and the role of renewables.
- Results can help guide and provide analytical support for EPRI’s renewable energy and climate change programs, as well as members’ resource planning and renewable strategy development.
- Close cooperation with other R&D organizations and energy modeling efforts, such as those at the National Renewable Energy Laboratory (NREL) and the Energy Information Administration (EIA), enhances information available to EPRI members and policymakers.

How to Apply Results
Members can apply data, information, and insights about the role of renewable energy to:
- Assess the status and potential of renewable generation technologies;
- Forecast the penetration of renewable energy in the generation portfolio mix for a range of scenarios; and
- Estimate the incremental impacts of adding renewable generation on fuel requirements, capital and O&M costs, and greenhouse and other pollutant emissions of the generation portfolio.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Modeling and Analysis of Renewable Generation in a Sustainable Portfolio: The update will use EPRI's comprehensive model, REGEN, to consider the latest climate and environmental policies and technology incentives that affect the deployment of renewable energy and the generation mix. Specific scenarios developed under this activity will be determined by the members. Model results will be analyzed and delivered through technical reports and workshops.</td>
<td>11/30/12</td>
<td>Technical Update</td>
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</table>

PS84B Biomass (069180)

Project Set Description
The Biomass Project Set conducts research and development in:
- Security of fuel supply and sustainable fuel delivery for electric power stations, including life-cycle analyses of biomass-based power and the carbon life-cycle of biomass
- Technologies for biomass power generation (including research on co-firing systems, direct-firing systems, gasification systems), the potential impact on combustion, emissions and environmental controls, and technologies for upgrading the properties of biomass fuels.

Project Set participants help identify the scope and priorities of collaborative research activities to be conducted. Technology transfer of information between members is an important element of active participation. Through this project set, EPRI provides a forum for information exchange among members on key biomass-related issues. In addition to receiving results of research, participants are kept informed of current regulatory issues surrounding biomass power generation through topical briefs as warranted.

<table>
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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P84.004</td>
<td>Biomass Supply Management</td>
<td>This project provides analyses of critical biomass supply issues to develop vigorous, durable fuel delivery for power stations.</td>
</tr>
<tr>
<td>P84.005</td>
<td>Power Generation from Biomass</td>
<td>This project develops information and technologies that can allow utilities to cost-effectively adopt biomass power within their generation and renewable energy portfolios.</td>
</tr>
</tbody>
</table>
P84.004 Biomass Supply Management (069181)

Key Research Question

The increasing number of renewable portfolio standards will drive many organizations to deploy biomass-to-electricity plants. In the late 1980s in California, the demand for biomass supply for power stations outstripped production. The result was a significant industry restructuring, including ownership changes and plant shutdowns. Today, as the electricity sector moves strongly into biomass-to-power, lessons such as this will be important for understanding the ever-evolving biomass fuel supply situation. Similarly, as more biomass enters the electric sector, there will internal and external pressure on utilities to ensure that supplies of biomass will last the life of the plant and beyond.

A more complete understanding of the existing and future biomass supply market is necessary to make informed fuel procurement and investment decisions. Utilities have vast experience in procuring coal and natural gas, and have developed considerable understanding of the key aspects of those fuels. However, procuring biomass in large, dependable supplies places utilities in unfamiliar territory, potentially dealing with a whole array of new issues, including:

- Large numbers of smaller suppliers, rather than a few large suppliers;
- Sharply defined supply seasonality;
- New, unproven supply chains and infrastructure developments, including the potential for aggregation and fuel upgrading;
- Uncertain future resource availability due to competition from other biomass consumers and critical water/land use priorities; and,
- Poor understanding of biomass markets, including cost structure and price risk mitigation options.

Perhaps most importantly, for biomass to be considered “renewable” by the public, the supply must be sustainable and have a minimal carbon footprint. The EPA has extended for three years its position that biomass is carbon neutral while additional information is developed and relayed to the agency. This window of opportunity will allow EPRI and others to provide critical information for the debate on neutrality. Because owners need to operate their biomass facilities for decades to make sound financial decisions, a sustainable, long-term supply is a paramount consideration. Considerable work remains on determining sustainability of various supplies.

Approach

This project will gather information from existing sources and industries, such as the forestry and agriculture industries. Lessons will be collected from the infrastructure development of industries such as pulp and paper and food products, and existing research will be mined for insights into land use. Best practices in procurement from other bio-based industries will be surveyed.

Because the utility sector’s needs are somewhat different from existing bio-products sectors, many of the practices and analyses will need to be adapted for deployment in the utility business framework. More specific modeling will be undertaken to understand biomass fuel procurement risk and risk management strategies.

Impact

The results of this work can be used to:

- Build a robust fuel supply chain;
- Manage supply and price risk;
- Understand competing uses for land, water, and biomass;
- Develop improved contracting methods; and
- Understand investment risk.
How to Apply Results

Members can use the results of this project to gain a deeper understanding of the biomass markets from lessons learned from other industries and implications of land-use modeling. Members also can develop their biomass procurement processes through improved contracting, application of risk management techniques, or employing supply chain hardening methods used by other industries. Finally, a deep understanding of the life-cycle implications of biomass-based electricity can provide some understanding of long-term supply security, and valuable insights for communicating with stakeholders about the carbon footprint of biomass electricity.

2012 Products

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<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Update on Biomass Power Life-Cycle Analysis:</strong> This report is a summary of new work on the physical and economic limits of supply in the face of biomass power life-cycle analysis. It will explore the notion of &quot;carbon debt&quot; and other contemporary topics.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>

**P84.005 Power Generation from Biomass (069182)**

**Key Research Question**

Most of the biomass combustion research issues have their roots in the fuel itself, which has very low energy density, contains high alkali and moisture levels, and generally is fibrous. These characteristics can lead to handling issues, poor capacity or conversion efficiencies, potential deposition issues within the unit, premature deNOx catalyst degradation, and difficulty in milling and transport to the boiler. In non-combustion biomass systems, these same fuel properties can cause similar problems, including poor-quality syngas and difficulty in gas cleanup.

**Approach**

For 2012, this project will work in up to five areas: technology transfer, cofiring systems, direct-firing systems, fuel upgrading, and gasification systems. Technology transfer will consist of webcasts and meetings to transfer experiences among funders and will include the annual Biomass-to Electricity Workshop. The work in cofiring will investigate methods for high-percentage cofiring (greater than 15%) and assess ash-related issues, including corrosion and slagging and fouling. Work on direct-firing systems will analyze the growing body of repowering projects to provide cost/performance profiles for each type. The effort in fuel upgrading will consist of test burns of torrefied biomass in utility-scale power generating units. The gasification work will assess biomass syngas cleanup technologies.

**Impact**

The work in biomass power generation can allow utilities to comply with renewable standards with greater efficiency, lower costs, and higher reliability.

**How to Apply Results**

The results of this work can support utilities as they formulate the details of their renewable energy strategy, providing clarity about equipment life (in the case of cofiring) or in selecting technology options (in the case of direct-firing systems). The information about economics and performance of upgraded fuel systems can be useful as utilities evaluate fuel supply scenarios, as well as operational impacts of biomass.
2012 Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Biomass Fuel Quality Impacts on Power Generators: Summarize findings and recent research on biomass fuel quality impacts on power generation, including corrosion mechanisms and mitigation and assessments of direct and cofiring slagging and fouling potentials.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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PS84C Solar (069184)

Project Set Description

This project set addresses integration of solar thermal energy into power plant steam cycles; solar technology testing activities at the Solar Technology Acceleration Center (SolarTAC) demonstration site; incorporation of solar thermal energy storage into solar thermal power plants; photovoltaic performance results; and advanced solar power cycles. It provides a forum for participants to exchange information on all solar electric technologies, applications, and market developments. Participants will learn about ongoing research and solar technology developments through industry tours, presentations from industry experts, and interaction with their peers.

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<tr>
<th>Project Number</th>
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<tr>
<td>P84.006</td>
<td>Solar Thermal Electric Research</td>
<td>Thermal energy storage and solar augmentation of power plant steam cycles have the potential to lower the levelized cost of electricity and provide greater operational flexibility. Multiple technologies and applications will be reviewed as part of this study using improved modeling tools.</td>
</tr>
<tr>
<td>P84.007</td>
<td>Solar Technology Acceleration Center (SolarTAC)</td>
<td>EPRI projects at SolarTAC primarily will be structured as supplemental projects, and the results of projects conducted by other SolarTAC members will be published as part of this project. EPRI will participate in codes and standards development that will be beneficial to testing and operating solar technologies in a commercial environment. In conjunction with SolarTAC, EPRI will update a database of commonly requested solar information such as briefs on emerging technologies, rules-of-thumb for water/land/fuel use, information about solar projects, solar resource assessment tools, and other information.</td>
</tr>
<tr>
<td>P84.008</td>
<td>Photovoltaic Research</td>
<td>Improving PV system reliability and reducing O&amp;M costs have the potential to increase system lifetimes and lower the levelized cost of electricity for PV projects. The current reliability and O&amp;M requirements for the leading technologies will be reviewed as part of this project, and the sources of performance degradation will be identified.</td>
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</table>

P84.006 Solar Thermal Electric Research (069185)

Key Research Question

Development of more than 10 gigawatts of concentrating solar power capacity is planned worldwide over the next five years. This project will evaluate technologies that will reduce cost and improve performance, with a focus on technologies that can provide firm, dispatchable power. Work will include evaluating new solar-augmented steam cycle applications; tracking the progress of thermal energy storage technologies; evaluating high-performance power cycles; and developing thermodynamic and economic modeling tools that will predict the cost and performance of projects located in various climate regions.
Approach

EPRI will continue the analysis of new applications for solar augmentation of steam cycles applications. This effort will include gathering information about industry projects that either are in operation or under development. It also may include evaluating solar integration with geothermal or oil-fired steam cycles. Building on work completed in 2010 on current solar thermal energy storage RD&D, this project will provide an update on current projects and obtain additional design and performance data as available for pilot and demonstration-scale storage systems. Work also will include further development of thermodynamic and economic modeling tools, and may include an independent evaluation of solar pressurized air receivers integrated with gas turbine cycles, to determine if this advanced cycle is technically and economically feasible.

Impact

This project will provide guidance on new solar application options for energy companies. Moving technologies from the pilot-testing phase to commercial-scale demonstrations can allow solar thermal technologies to be more readily adopted in utility generation portfolios.

How to Apply Results

The results and insights gained in this program provide expanded options to plant owners who wish to maximize existing plant assets or develop new solar assets, reduce their carbon footprints, and gain valuable experience with solar thermal electric systems. Enhanced modeling tools can allow project developers to make more educated decisions about solar projects in different locations.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Solar Augmented Steam Cycles Applications:</strong> This will be a continuation of previous solar augmented steam cycles studies, focusing on a detailed cost and performance assessment of greenfield natural-gas / combined-cycle and coal-fired power plants, and characterizing the cost differential of locating the plant in a range of solar resources.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>State of Thermal Energy Storage Development:</strong> This report will provide an update on the progress of solar thermal storage by documenting existing projects, updating progress on new and novel technologies, and identifying the current pipeline of thermal energy storage projects. To the extent that information is available, capital costs and cost projections for the leading thermal energy storage projects will be compiled.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>

P84.007 Solar Technology Acceleration Center (SolarTAC) (069186)

Key Research Question

Energy companies need a place to test and validate emerging solar technologies in a commercial setting in order to make accurate comparisons of technology options. The Solar Technology Acceleration Center (SolarTAC)—a venue for solar research, technology testing, and demonstration located in Aurora, Colorado—is a central location for collaborative technology demonstration and testing.

Approach

This project details activities as part of EPRI’s membership in SolarTAC. Membership allows EPRI to conduct projects on-site and provides access to shared R&D projects conducted by other SolarTAC members. Focus areas include comparisons of photovoltaic technologies and pilot-scale testing of solar thermal generation and storage technologies.
Impact
This program offering will provide real data on emerging solar technologies that can allow energy companies to make more educated solar investment decisions.

How to Apply Results
The results and insights gained in this program can provide critical knowledge to energy companies that wish to develop new solar assets and understand the technology options.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Solar Fact Book Update:</strong> Annual update of the Solar Fact Book, a concise, relevant solar information repository with references to more detailed EPRI studies. This database encompasses commonly requested solar information such as briefs on emerging technologies, rules-of-thumb for water/land/fuel usage, information about solar projects, solar resource assessment tools, and other relevant information.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Annual SolarTAC Report:</strong> An annual summary of EPRI SolarTAC activities and update of results of projects conducted by other SolarTAC members.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>

P84.008 Photovoltaic Research (071169)

Key Research Question
As utilities expand their ownership of photovoltaic (PV) assets, there is a particular need for long-term performance, reliability, and operating and maintenance (O&M) data for different types of technologies. A substantial base of scientific knowledge exists for crystalline silicon PV technologies, but this base still is being built for other leading PV technologies.

Approach
This project will review available data and literature to assess long-term performance and O&M costs. It will explore condition-based monitoring approaches and self-diagnostics for inverter/controller/energy management that would allow prediction of remaining lifetime. This project also may identify R&D tools and expertise to better understand the properties of PV system interfaces that can lead to instability or failure.

Impact
An improved understanding of degradation mechanisms could lead to R&D that would increase module lifetimes. Reducing downtime for unplanned O&M would result in higher annual electricity generation. Extending the lifetime and improving reliability and availability through reduced O&M can lower the levelized cost of electricity.

How to Apply Results
A better understanding of reliability, performance degradation, and O&M requirements for different technologies can help energy companies make knowledgeable choices about solar project investments and provide guidance on how to operate and maintain PV projects.
2012 Products

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tr>
<td><strong>Performance and Reliability of Central Station PV Plants:</strong> This technical update will summarize available data that assesses long-term performance and O&amp;M costs of central-station solar PV plants. The report will explore condition-based monitoring approaches and self-diagnostics for inverter/controller/energy management that would allow prediction of remaining lifetime.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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**PS84D Wind (069188)**

**Project Set Description**

The Wind Project Set assesses advanced wind turbine technologies and evaluates wind asset management technologies and strategies. Advanced technology assessments will include review of relevant reports and patents, analyses of technology strengths and weaknesses, and forecasts of likely paths for R&D. Asset management research will address application technologies to allow condition monitoring and provide understanding of major component reliability and reductions in O&M costs, with field data collection to guide the efforts.

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<th>Project Number</th>
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<tr>
<td>P84.009</td>
<td>Wind Power Technology Assessment</td>
<td>This project provides in-depth advanced wind turbine technology assessments, which include reviews of reports and patents; analyses of technology strengths and weaknesses; forecasts of likely paths for R&amp;D, demonstration, and early deployment of a selected two to three promising technologies. This project also includes an assessment of the current and likely future performance and cost impacts of applying the new technologies.</td>
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<tr>
<td>P84.010</td>
<td>Wind Power Asset Management</td>
<td>This project develops applications of new technologies to allow condition monitoring, understanding of major component reliability, and reductions in O&amp;M costs. It will include collecting field data to guide the efforts.</td>
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**P84.009 Wind Power Technology Assessment (069189)**

**Key Research Question**

Objective assessments are needed of the status, technical and economic feasibility, and the requirements for further development and demonstration of new wind turbine and associated technologies. The R&D scope includes blades and rotors, drive trains, gearboxes, generators and power electronics, sensors and controls, towers and foundations, and other components for both land-based and offshore wind projects.

**Approach**

This project will review technical papers, reports, and patents; make site visits to technology developers and field demonstration projects; and prepare annual reports on new wind turbine and associated technology.

**Impact**

Results will identify the most promising technologies that can be expected to improve the performance, reliability, and cost of future wind power generation, and select the ones with more potential for further detail technical and economic analysis.
How to Apply Results

Utilities can use the information provided by this project to assess potential impacts of changing wind turbine technologies on design, performance, reliability, and cost of applying these technologies at future wind generation plants, and analyze potential opportunities for investment in new wind turbine technology.

2012 Products

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<tr>
<td>Assessment of New Wind Power Technology - 2012: The scope of this assessment includes an</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<td>in-depth review of two to three selected key wind turbine technologies, including reports and</td>
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<td>patents; analyses of technology strengths and weaknesses; forecasts of likely paths for R&amp;D,</td>
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<td>demonstration, and early deployment of promising technology. An assessment of current and</td>
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<td>likely future performance and cost impacts of applying the new technologies will be</td>
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<td>summarized.</td>
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P84.010 Wind Power Asset Management (069190)

Key Research Question

During 2010, the rated capacity of worldwide wind power generation reached 195,000 megawatts (MW), and U.S. capacity reached 40,000 MW. Effective management of the resulting large fleet of wind turbines requires asset management tools to monitor, operate, and maintain the wind turbines to maximize reliability and annual power generation.

Approach

This project will apply and test advanced technologies to develop and populate a database of wind turbine component reliability and to monitor the condition of major wind turbine components, including rotors and blades, gearboxes, generators, yaw drives, and sensors and controls. The database development will apply Operational Reliability Analysis Program (ORAP) technology now used to tabulate reliability data for combustion turbines. Condition-monitoring technology includes online condition monitoring and supervisory control and data acquisition (SCADA) data trend analyses of individual turbines to detect evolving component wear and tear. A report will review the status of the O&M and asset management technologies and their potential to reduce O&M costs.

Impact

The results of this project have the potential to improve the reliability and annual generation of the wind turbine fleet, and reduce O&M costs of wind farms.

How to Apply Results

This project applies the database of wind turbine component reliability to monitor individual turbine reliability relative to that of the population of wind turbines.

The O&M report will identify the new asset management technologies that offer the most potential to reduce O&M costs at operating and new wind farms.
**2012 Products**

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<tr>
<td><strong>Wind Turbine O&amp;M and Asset Management Technologies Guidebook</strong></td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Applications Summary:</strong> During 2012-2013, this project will develop and test a guidebook on wind turbine O&amp;M and asset management. This guidebook will be a compendium of information and O&amp;M procedures, condition monitoring, and nondestructive testing of gearboxes, cables, turbine blades, and other components. It also will cover technologies for managing large fleets of wind turbines to maximize energy capture and minimize O&amp;M costs.</td>
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<tr>
<td><strong>ORAP Wind Turbine Component Reliability Database Progress Report:</strong></td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>The Operation Reliability Applications Program (ORAP) provides a database of wind turbine component reliability for use in reliability-centered maintenance programs at operating wind power projects. This technical update will provide a progress report on the wind ORAP database development activities.</td>
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**PS84E Geothermal (069191)**

**Project Set Description**

This project set will promote collaboration between geothermal plant operators, developers, and owners by documenting common industry problems, providing solution guidelines, and conducting targeted research and development to improve the performance and reliability of geothermal technologies. Nondestructive evaluation, corrosion management technologies, and reliability-centered maintenance will be applied to existing plants to improve performance and reduce costs. New technologies for moderate- and low-temperature geothermal conversion will be evaluated for technology readiness and application limits for commercial viability. Enhanced/engineered geothermal systems will be evaluated as potential candidates for development and demonstration. Participants in this project set also will have access to a new Geothermal Interest Group formed to engage owners/operators of current geothermal facilities, identify technology challenges, and develop targeted research opportunities.

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<tr>
<td>P84.011</td>
<td>Geothermal Operations and Maintenance</td>
<td>This project will promote collaboration among geothermal plant operators, developers, and owners in documenting common industry problems and developing solutions. These problems/solutions will be incorporated in guidelines that include industry best practices and become the bases for a handbook on geothermal O&amp;M.</td>
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</table>
| P84.012        | Assessment of Geothermal Power Technologies        | This project will provide the engineering and economic analysis of promising new technologies with significant potential for extracting energy from geothermal sources, including:  
  - Enhanced geothermal systems (EGS), also known as hot dry rock (HDR), building on recent applications under way in Australia and Europe. The project will identify and conduct preliminary engineering and economic analysis to support participation in two demonstration projects by 2014.  
  - Moderate- and low-temperature geothermal from water resources common in many countries, and new technologies beginning to appear that allow these resources to be developed commercially.  
  - Geothermal power production co-produced from oil and gas wells in sedimentary basins. |
P84.011 Geothermal Operations and Maintenance (069192)

Key Research Question

Geothermal maintenance costs are about twice those of fossil fuel plants, with fixed O&M costs dominating. Average plant availability in the United States is less than 80% due to problems of corrosion, deposition, and erosion, which are characteristic of the geothermal environment. Comprehensive geothermal O&M industry guidelines, based on actual plant experience and applying new technology to ensure high plant availability, are needed if geothermal power generators are to remain competitive with other sources of power. These guidelines will serve as an independent engineering resource to evaluate plant operations and maintenance and to identify best industry practices for improving availability and profitability.

Approach

This project will develop guidelines to support members in obtaining the following services for geothermal plant evaluations:

- Independent evaluation of process requirements, materials selection, and plant equipment specification.
- Guidelines for a preventative maintenance program to minimize forced outages and to maximize turbine in-service periods.
- Training and technology transfer to ensure operators develop the required levels of operational skills.
- Recommendations for systems re-engineering in response to changing production conditions and assessment of deposition problems.
- Turbine performance improvement evaluations, performance testing, and analysis of deposition problems.
- Condenser/cooling circuit optimization and chemical dosing recommendations.

Impact

- Results will provide an O&M cost reduction opportunity on the basis of lessons learned and collaborative experience sharing on materials, nondestructive evaluation (NDE) technologies, and operator training.
- Guidelines for a preventive maintenance in-service inspection (ISI) program and turbine performance improvement evaluation can improve availability and production.

How to Apply Results

- Participate in training and technology transfer work-outs to ensure operators develop the required levels of operational skills.
- Develop and apply geothermal O&M guidelines and member handbooks, which reflect new experiences and technology improvements, to support improved practices and procedures.
- Define technical support on materials, chemical treatments, turbine performance, deposition problems, and reservoir management.

2012 Products

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<tr>
<td>Geothermal O&amp;M R&amp;D Needs: To better understand the confluence of the geothermal industry and utility O&amp;M research needs, an interest group will be formed, including both traditional EPRI members and representatives from the geothermal industry. Immediate, near-term, and long-term geothermal O&amp;M needs will be identified with the intent of guiding future work in these areas.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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P84.012 Assessment of Geothermal Power Technologies (069193)

Key Research Question
Engineering and economic analysis of various geothermal resource qualities and related technologies is needed to provide input for decisions regarding power production options. The near-term focus includes low-temperature power conversion and reverse-air-conditioning-cycle binary generators. Additional needs include feasibility assessment and proof of technology performance for enhanced/engineered geothermal systems (EGS). Design analysis and preliminary engineering also are needed for advanced geothermal EGS.

Approach
The technology selection will be based on member interest. The approach will be to use available engineering experience from geothermal, oil, gas, and other relevant sectors as a starting point. Areas in which efficiency improvements and risk reductions are necessary for successful demonstration of the technologies will be identified, and mitigation procedures will be proposed.

Impact
- Provide detailed engineering and economic evaluations of the potential of geothermal moderate- and low-temperature technology applications to produce electric power. Most geothermal power plants in the future likely will be binary-cycle plants.
- Participate in EGS collaborative cost/risk assessment projects to validate technology potential in the future.
- Become familiar with expected engineering and economic challenges and operational lessons learned from existing facilities.

How to Apply Results
- Use data for preparation and review of renewable requests for proposals (RFPs) for low-temperature geothermal distributed generation or EGS geothermal plants for renewable electricity to meet RPS requirements.
- Learn about development of small (up to 15 MWe), remotely operated, low-temperature geothermal generation projects based on low-cost modular strategies, as well as geothermal EGS plants projects to generate baseload renewable electricity.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation of Advanced Binary Geothermal Designs: Cycle efficiency of binary geothermal plants utilizing low- to moderate-temperature geothermal resources is critical to the ability to produce cost-effective power. New novel high-efficiency turbine designs may result in greater cycle efficiency, reduced parasitic pumping loads, and reduced costs of energy. This project will update the 2010 study Engineering and Economic Evaluation of Low-Temperature Binary Geothermal Power Plants, using these new turbine designs to assess their effect on key parameters, including geothermal fluid requirements, parasitic loads, net power output, capital costs, and costs of electricity.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
Supplemental Projects

Flat Plate Photovoltaic Collaborative Testing at Solar Technology Acceleration Center (070976)

Background, Objectives, and New Learnings

Traditional crystalline silicon photovoltaics (PV) are and will continue to be costly, but there is insufficient experience with many of the newer, potentially cheaper PV technologies to warrant large-scale, long-term investment. The efficiencies of new flat-plate technologies are tested extensively in laboratories, as cells and as modules, to make manufacturing decisions. But only unbiased larger-scale and longer-term trials in the actual operating environment (i.e., outdoors) will suffice for commercial acceptance of these new technologies. Banks and utilities are likely to wait for the results of early field tests to gain confidence in the reliability of new PV technology.

A recent EPRI study (EPRI document # 1021320) compared six categories of commercially available PV technologies and estimated their performance in different climates. These technologies, and specific products within these categories, have achieved different levels of maturity. Several new products have the potential to be lower cost with better performance than today’s commercially available technologies.

The Solar Technology Acceleration Center (SolarTAC) is the largest test facility for solar technologies in the United States. It offers a venue for the collaborative development of solar energy technologies and products (see www.solartac.org). EPRI’s membership in SolarTAC provides a proving ground for both emerging and near-commercial technologies.

This collaborative project will reduce performance uncertainty of PV technologies through an independent assessment in a real-world operating environment. The project could help pave the way for future PV projects to be developed at lower cost and with better performance.

Project Approach and Summary

The project objective is to independently assess the performance and reliability of a variety of PV technologies in a real-world setting. This project will assess the site requirements, installation, commissioning, performance (at least one full year of operation), reliability, and O&M requirements of multiple PV technologies.

The demonstration testing will be initiated at SolarTAC in Aurora, Colorado, and additional locations also may host demonstrations to better understand performance in a broader range of climates. Systems will likely be in the 5-10 kW size range. The number of systems to be tested will be determined by available funding.

During installation, EPRI will work with on-site developers to understand any installation issues. Standard testing protocols will be developed and monitoring systems implemented to capture key performance metrics. A suite of meteorological measurements will be taken to compare expected performance with actual system outputs. Ramping during cloud transients is of particular interest. O&M activities and expenditures will be reported and best practices for preventative maintenance will be recommended based on experience. Performance data will be analyzed to identify lost generation potential, and the failure modes and countermeasures implemented will be documented and reported.

As with any early systems, significant learning is expected to take place, and best practices will be communicated to participants throughout the project. Potential means of improving the cost-effectiveness of the systems will be identified by EPRI and technology providers.

Benefits

This program offering will provide real data on emerging solar technologies that will allow energy companies to make educated solar investment decisions.
**Advanced Nondestructive Evaluation and Structural Integrity Assessment of Wind Turbine Blades (071965)**

**Background, Objectives, and New Learnings**

With the development and deployment of 5 megawatt (MW) and larger wind turbine systems, wind turbine blades are reaching lengths in excess of 60 meters and weights greater than 17 metric tons. Blades of 100 meters length already are being designed for off-shore use. Varying loads, combined with millions of operating cycles during the wind turbine blade design life, create challenges in determining their condition. Production-related and in-service flaws in the blade skins and spars can result in cracks and other damage that grows steadily over time. This leads to expensive blade repair and replacement and sometimes well-publicized catastrophic failures. In-service operating conditions, environmentally assisted degradation, and fatigue also can lead to premature blade failure.

This project will refine laser shearography examination techniques for *in-situ* flaw detection of in-service blades. Composite degradation and flaw analysis models will be developed that can enable wind turbine owner/operators to evaluate and address flaws that have been detected during pre-service and in-service inspections.

**Project Approach and Summary**

The project objectives are to:

- Refine and demonstrate laser shearography techniques to detect relevant flaws in wind turbine blades in pre-service or in-service conditions; and
- Develop analysis models and processes for evaluation of flaws and aging degradation in wind turbine blades.

The project will be conducted as two parallel activities — laser shearography development, and flaw analysis model development.

**Laser Shearography Refinement and Demonstration**

- Laser shearography techniques previously developed by EPRI will be refined to improve detection of typical composite wind turbine blade flaws. These techniques will be applicable to blades in fabrication, pre-service, or in-service conditions.
- Distance laser shearography techniques will be developed and refined for detecting in-service related damage and flaws for *in-situ* blades of operating wind turbines. This technique allows for inspection from the ground level with the turbine and blade resting in a steady position. The distance laser shearography technique will be field tested on in-service wind turbine blades to demonstrate its operation and detection capability.
- A summary and comparison of results from the testing of shearography and other NDE techniques applicable to wind turbine blades will be included.

**Development of Flaw and Degradation Analysis Models**

- Flaw and aging degradation analysis models will be developed in conjunction with the Sandia National Laboratories’ Blade Reliability Collaborative. Model outputs will be used to develop processes to evaluate and disposition flaws and degradation detected in wind turbine blades. The models will be refined to include flaw data gathered during laser shearography testing activities.
- Flaw evaluation analysis processes will be developed to allow owner/operators to evaluate flaws and blade degradation, enabling “return-to-service” and cost-effective asset management decisions.

**Benefits**

The technologies supported by this project can allow the wind turbine to be operated more reliably and efficiently. The improved shearography techniques will result in more thorough structural assessments of blades by making it easier to detect flaws and degradation for post-fabrication, pre-installation, or in-service
examinations. Aging degradation and flaw analysis models will allow owner/operators to make critical asset management decisions about the wind turbine blade life.

As of the end of 2010, the rated capacity of worldwide wind power exceeded 150 GW and continues to grow at a rate of 20 to 30% per year. A system that supports condition-based inspections of wind turbine blades and assessment of blade structural integrity is critical to reliable, long-term operations. Integration of advanced nondestructive examination techniques with engineering analysis and flaw evaluation processes will provide the tools necessary to proactively maintain wind turbine integrity and improve overall reliability.
National Biomass Supply Study (071847)

Background, Objectives, and New Learnings

Competing demands for U.S. biomass resources and resulting impacts on regional feedstock availability could have a significant impact on the ability of the liquid biofuels industry to transition to lower-cost feedstocks, such as wood, agricultural residues, and energy crops, as well as on the ability of U.S. electric utilities and consumers to meet renewable portfolio standards (RPS) and transition to lower carbon-footprint sources of electricity. Promulgation of regulations that place a cost on CO₂ also will affect this situation as biomass-to-power applications become increasingly cost-competitive. This increased competition for biomass feedstocks will create technical and economic risks for the government, industry, and investors, and has the potential to impede commercialization of bio-energy in the United States at a meaningful scale.

This project will analyze these competing demands in a unified fashion to develop insights and learning on how much biomass is available for public-good use in fuels and power combined, and what cost the public would pay for the biomass at various deployment levels. It also will provide new information about the carbon life-cycle aspects of the various biomass-to-energy end use pathways that will help inform public debate.

Project Approach and Summary

A comprehensive study will be performed of the impacts of competing demands on biomass resources that will result from the use of biomass for liquid fuels and power applications. Biomass resources to be studied will include terrestrial crops (wood, forest and agricultural residues, and energy crops). Other potential fuel sources (e.g., animal waste) will be evaluated for consideration by the sponsors.

This project will represent a collaboration between EPRI and those interested in the potential size of the liquid fuel biomass demand, including liquid fuel producers, automakers, and power producers. The work will be executed in collaboration with EPRI's Environment sector. Industrial partners will provide input to the research team in identifying priority research areas, quantifying targets for investment/commercialization, identifying scenarios to evaluate, and providing real-world input data to populate appropriate analytical models.

Benefits

This project can help participants and policymakers understand the potential sustainable market for biomass and the market's size relationship to cost. This information can help companies inform regulators and manage the risks associated with over-committing to biomass in the face of competition.
Torrefaction Pilot Testing (071809)

Background, Objectives, and New Learnings

Background:
Biomass torrefaction, derived from a process traditionally used to dry and roast coffee beans, involves treatment of raw biomass in an oxygen-free environment at a temperature of approximately 250°-300°C. The resulting solid torrefied char generally contains up to 30% more energy content per unit mass than the raw feedstock. Compared to raw wood products (chips and pellets), torrefied biomass contains a far lower amount of volatiles and virtually no water. Torrefied biomass allows for higher levels of mass densification through pelleting/briquetting than regular biomass. Torrefied pellets are hydrophobic and likely do not degrade physically. Recent EPRI tests confirm that torrefied pellets/briquettes can be produced from a wide variety of feedstocks (sawdust, willow, larch, verge grass, demolition wood, and straw), yielding similar product specifications. Additionally, EPRI completed an engineering study to explore the feasibility of small torrefaction facilities (2 tons/hour to 5t/h of product capacity). This project will test a pilot torrefier to validate performance estimated in the prior EPRI study and conduct small co-firing tests at host plants, using test-produced torrefied chips and pellets.

Objectives:
- Independent test of a pilot scale 1-2 tons/hour torrefier using several woody and herbaceous feedstocks to assess quality of processed products, process energy efficiency, flexibility, mass yields, and emissions.
- Produce approximately 100 ton of product (chips and pellets) from each feedstock to support subsequent burning tests at host plants.
- Participate in burning tests at host plants to extract lessons learned on the application of this engineered fuel.

New learning:
- In-depth knowledge of torrefied biomass production and key issues affecting quality, emissions and economics.
- Large-scale burning tests at host plants using this engineered fuel in co-firing with coal.

Project Approach and Summary

The torrefaction process demonstration will be performed in collaboration with Idaho National Laboratory (INL), using its process demonstration unit (PDU) equipment, and will use on-site facilities, expertise, and extensive instrumentation/control and analyses capabilities.

The project will produce torrefied biomass from three different types of feedstock (woody, perennial grass, and agricultural waste) in sufficient quantity (approximately 100 tons/specie of chips and pellets) to support pilot burning tests at host power plants. The torrefaction technology selected will be integrated with the INL-PDU decomposition, grinding, drying, and densification modules. The process will be supervised from a centralized control room and will include a chemical laboratory for sample quality control.

Test burns using the torrefied biomass then will be conducted at host sites. These tests will include assessment of torrefied biomass handling/grinding, combustion efficiency, emissions, and ash characterization.

Benefits:
- Reduce the technical and economic risk of adopting this new high-potential engineered fuel to existing coalburning plants.
- Expand the use and geographic range of economic biomass to energy production.
- Accelerate application of commercial torrefaction technology for high-ratio biomass co-firing.
- Optimize operating performance to meet required fuel specifications from a variety of biomass feedstocks.
Development of Continuous Pre-Treatment Process for Upgrading Biomass (072062)

Background, Objectives, and New Learnings

Carbon mitigation and sustainability issues for energy production are driving the need for new technologies to foster renewable biomass utilization. However, biomass use in existing power generation systems as well as gasification plants is hampered by the logistics of transport, the difficulty of handling, and the potential for undesirable inorganic components in biomass to react unfavorably in existing systems. Avoiding biomass-induced fouling, agglomeration, corrosion, and poisoning of catalysts will reduce investment and operation costs, increase efficiency, and contribute to expanded use of biomass and waste materials for the production of energy and liquid fuels.

The biomass washing-leaching process eliminates from the feedstock chlorine and alkali metals, and substantially reduces sulfur and phosphorus as well as nitrogen and heavy metals. The process can use off-the-shelf technology for milling/shredding, leaching baths, processing of the leachates and waste water treatment.

Chemical solvents specifically tailored to remove the inorganic elements from 10 different biomass and waste materials and optimum sets of parameters for the leaching process were successfully tested at batch bench-scale in 2010-2011 through an EPRI Technology Innovation sponsored project, confirming the high potential of this technology.

Project Approach and Summary

In collaboration with industrial partners and the developer of a high-potential biomass washing-leaching technology, validated at bench-scale through previous EPRI research, this project will design and assemble a 1 ton/hour pilot plant to optimize the continuous and integrated process and set the basis for a larger pre-commercial demonstration project. Activities will include:

- Optimization of an integrated continuous leaching process operation, including downstream mechanical dewatering/pre-drying and leachate recovery systems
- Production of approximately 4 tons of clean biomass material from four (4) different feedstock to be later used in combustion and gasification pilot tests

Benefits

- Successful demonstration of a continuous and integrated process for biomass washing-leaching will allow expanded use of sustainable biomass feedstock for energy production.
- Increase the understanding of the washing-leaching technology and its potential, contribute to reduce the technological and economic risks of clean biomass production, and facilitate decisions on long-term supply commitments.
- Provide for optimization of the continuous leaching process and the development of biomass upgrades to reduce costs and maximize efficiency of a first-of-a-kind (FOAK) demonstration plant with a 10-15 Kton/year capacity.
Regional Deployment and Implications of Renewables (072069)

Background, Objectives, and New Learnings

Policies to deploy renewable energy are spreading rapidly across the United States and around the world. Investment tax credits, production tax credits, many variants of renewable portfolio standards, clean electricity standards, feed-in tariffs, and other mechanisms have been proposed or are in-place. In the United States, 29 states and the District of Columbia have adopted renewable incentives. California is now targeting 33% of electricity from renewable generation by 2020. The federal government also has described the general outlines of a Clean Electricity Standard that would require 80% of electricity to be generated by "clean" technologies by 2035 and either market- or regulation-based climate policies could further incentivize renewable deployment. Impacts on costs, electricity rates and environmental emissions, and compliance options are key research questions to be examined. Each state and region of the United States has unique resources, existing generation, transmission and distribution assets, load patterns, and other considerations that will affect strategy for complying with these regulations and considering the economic incentives.

Because of its intermittent nature, location dependence, low energy density and capital intensiveness, widespread deployment of renewable energy can create many challenges for electric companies. Variability coupled with low marginal cost of operation will lead to increased cycling of dispatchable assets and can provide challenges to the electricity market designs (as evidenced in Europe). Wind resources, transmission, electricity storage and natural gas generation are intertwined in ways we are just beginning to understand.

This project will build upon data and models developed and applied as part of EPRI’s US regional model development to examine the economic potential of renewable resources on a state-by-state basis, to understand broad-scale regional issues for tying in these resources, and examining interactions with other generation, energy storage and demand under a variety of possible future policies.

Learning from this project may inform company compliance strategies as well as provide valuable input to policymakers as they craft future renewable, energy and environmental policies. Key insights will be published as a technical update.

Project Approach and Summary

Project participants will work closely with EPRI staff to develop and review regional analyses of renewable resources, high-level integration issues, and policy implications. This work will provide the public as well as electric power companies with information associated with making the most economically sound choices for renewable energy on a regional basis. Basic analyses can be conducted if there is only one funder in a region; much more detailed analyses can be conducted when there are multiple funders in a region. Key elements include:

- **Resource evaluation.** EPRI will work with funders to explore 14 years of hourly wind resource data at the state level in order to get a better understanding of wind potential and its correlation with load. A similar investigation will be made of solar opportunities, both photovoltaic technologies and concentrating solar power, where appropriate. Biomass supplies under different energy policies and other renewable resources will be investigated. The biomass resource assessments will explicitly recognize the cross-sector impacts on agricultural and forestry markets through land use modeling.

- **Analysis.** Analyses will be conducted to examine the implications of a range of energy and environmental policies as well as to understand the implications of key uncertainties, e.g., natural gas price. The tools utilized will depend upon the questions specific to the regions, but will likely include a dynamic version of EPRI’s regional modeling framework which simulates the economy through 2050, a one-year version of the model which allows examination of 8760 hours of resource supply and load data (allowing for examination of energy storage as an option for dealing with intermittent generation), and possibly a more detailed, unit commitment model.
These analyses can help companies develop renewable compliance strategies, anticipate market and asset value impacts as well as operational challenges (e.g., generation cycling) from a rapid influx of renewable generation in their region, and communicate critical insights on the opportunities and costs to legislators, regulators and the public.

Benefits

Companies and the public at large are expected to gain a better understanding of regional renewable resources and deployment implications under a range of renewable, energy and environmental policies. These policies can affect not only investments in renewable generation and renewable compliance strategy, but also can impact investment decisions for both upgrades of existing generation and new, non-renewable generation. Key insights from analyses can help inform policymakers and the general public.
Field Demonstrations of Wind and Solar PV Plants Providing System Frequency Response and Regulation (072096)

Background, Objectives, and New Learnings

Wind and solar PV generation has generally not been designed to supply inertia, primary frequency response (governor), or secondary frequency response (automatic generation control [AGC]) to the system. In systems in which large amounts of these variable resources have been installed, there are periods of time during which an increasing percentage of the load is served from these resources pushing more conventional generators, which typically supply these needed functions, off the system. As a result, studies of systems anticipating high wind and/or PV penetrations have shown potential stability concerns as penetrations increase if the renewable resources are not controlled in a way that provides some similar inertial and primary frequency response. In response to these concerns, system planners and operators along with wind turbine manufacturers and plant owners/operators have begun to consider the extent to which wind plants might be able to provide these functions with some systems establishing requirements. In addition, some wind turbine generator (WTG) manufacturers have begun testing and deploying new control packages that allow the WTGs to emulate inertial response. To date, however, there has not been a succinct, focused effort for most North American systems to evaluate the levels at which systems might be beginning to have these potential stability issues and to evaluate the effectiveness of wind and solar PV plants to supply these needed reliability functions as they push conventional generation offline. This project will provide for actual field verifications of the ability of wind generation and solar PV generation plants to adequately supply inertia, primary frequency, and AGC response when interconnected to the bulk power system. This work will give system operators a better understanding of the types of advanced controls that contribute to these required system functions.

Project Approach and Summary

EPRI will partner with the National Renewable Energy Laboratory (NREL) to use its utility-scale test wind turbines to test various active power control schemes for contributing to system frequency responsive functions. EPRI will also pursue a partnership with a commercial wind plant that has implemented or is willing to implement a commercially available active power control package offered by the wind turbine manufacturer for the turbines used in the plant. For both the NREL test turbines and a commercial plant that will be potentially identified, EPRI will conduct measurement and verification (M&V) of the turbine/wind plant active power output during specific frequency disturbances that naturally occur on the interconnected power system.

EPRI will also work with the University of Texas at Austin (UT-Austin) to evaluate any relationships between online wind generation and the Electric Reliability Council of Texas, Inc. (ERCOT) system frequency responsiveness for disturbances in the ERCOT system. This evaluation will use synchrophasor data collected across the ERCOT system as part of a joint EPRI and UT-Austin synchrophasor network project.

Benefits

This project will give system operators and planners an understanding of the abilities of wind generation and solar PV generation to effectively contribute to the frequency responsive needs of the power system during disturbances and steady-state operation (AGC). The M&V effort will confirm whether emerging renewable resources can provide the functionality of the conventional generation that they might replace or whether there are limitations to the frequency responsiveness of wind and PV with advanced controls. If the effectiveness of these controls can be confirmed, one of the major concerns that have been voiced relative to the potential system reliability impacts of variable generation will be removed.
Power Delivery & Utilization

Developing technologies and approaches to facilitate higher levels of grid reliability, efficient use of energy, and grid transformation

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183 Cyber Security and Privacy
   183A: Cyber Security and Privacy Technology Transfer and Industry Collaboration
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Overhead Transmission - Program 35

Program Overview

Program Description
Transmission companies face issues such as improving safety and reliability, as well as reducing operations and maintenance (O&M) costs. They are also seeking ways to increase transmission capacity without making large capital investments. Reducing capital expenditures for new and refurbished equipment is another priority.

This EPRI research program is designed to address the research needs of transmission asset owners and operators. The program includes projects focused on specific components (e.g., insulators, compression connectors, and crossarms) as well as projects focused on issues (e.g., lightning and grounding, live working, and transmission capacity). The program delivers a blend of short-term tools such as software, reference guides, and field guides, together with longer-term research such as component-aging tests and the development of sensors for monitoring the performance of line components.

Research Value
With the knowledge acquired through this research program, program members will have access to information that can provide them:

- Improved management of aging transmission line components
- Improved inspection and assessment tools and techniques
- Enhanced lightning performance reliability
- Tools to increase efficiency of transmission line design
- New live working techniques and procedures
- Schemes to get more capacity out of existing overhead lines
- Improved approaches to selecting, applying, inspecting, and assessing insulators
- Information on emerging transmission line sensing and inspection technologies

Approach
EPRI research in overhead transmission will yield data and knowledge that will benefit program members. This information will be provided in a number of forms and is expected to offer members both short- and long-term value. A comprehensive transmission line inspection and assessment reference guide, the Yellow Book, is continuously updated to ensure that it provides members with the most up-to-date, comprehensive understanding of transmission component behavior, inspection technologies, and line effects. Field guides and training software help workers identify levels of component deterioration and take corrective action in a timely fashion. Operators can learn to improve capacity through the use of thermal and corona models of overhead conductors operating at high temperatures and through understanding of the effect of high-temperature cycling on conductor systems. Methods and tools are being developed to maintain transmission components and extend their life. Transmission line and foundation design tools enable members to incorporate the most current industry knowledge into their development plans.

The program also performs long-term laboratory experiments to better understand the aging and failure mechanisms of structures and line components. Corrosion labs create environments to better understand the impact of corrosion above and below ground. Insulators are tested for aging and degradation to better understand their long-term performance characteristics.

Accomplishments
The Overhead Transmission program has delivered valuable information that has helped its members and the industry in numerous ways. Some examples include:
• EPRI Software for Polymer Insulators Electric Field Calculations (EPIC): Version 3.1 is used to evaluate the corona performance of polymer insulators, whether in-service or as part of a new design. An EPIC 3D model can be created from scratch in under 15 minutes, whereas the same model in traditional software can take hours. The software helps users reduce the risk of transmission line polymer insulators failures caused by the degradation of the rubber weathershed system due to corona activity.

• Conductor Cleaning Tool: This device is a more efficient, less costly tool for cleaning high-voltage conductors. The new tool uses a detergent-like solution, enabling crews to thoroughly clean conductors without the traditional steps of unstranding the wires in the conductor and then restranding them after each strand is cleaned.

• Visual Inspection of Avian Issues on Transmission Structures: This EPRI report, one in a series of practical guides designed as reference aids for personnel working in the field, visually catalogs the various condition issues that commonly affect transmission lines due to avian interaction. It presents photographs and short written descriptions of the conditions, and lists associated causes, failure modes, and impacts. The guide is printed in color on high-quality paper and is ring-bound.

• Lightning Performance Prediction Software: TFlash, Ver 6.1, is used to evaluate the performance of existing lines or help design new transmission lines. It enables users to build models of transmission lines and then analyze their susceptibility to lightning. The software provides many tools to help users design improvements to power lines to reduce lightning outages.

• Rating methodologies and complementary software have helped power utilities achieve higher transmission capacity ratings safely and reliably for existing systems.

Current Year Activities

In the coming year, this research program expects to accomplish these objectives:

• Updated Inspection and Assessment Guidelines for Transmission Lines (the Yellow Book)
• Tools and mitigation techniques to address sub-grade and conductor corrosion
• Thresholds for compression connectors inspection tools
• Inspection and assessment of crossarms
• Foundation analysis and design
• Live work with high-temperature conductors
• Transmission Line Workstation (TLW)
• Composite component accelerated aging results
• Software to aid in selection of corona rings (EPIC)
• Updating of transmission capacity guidebook, and development completed of a “smart tool” for selecting suitable options for transmission capacity upgrades
• Improvement of transmission capacity software and data analysis program for rating methodologies
• Development of additional instrumentation for increasing power flow
• Guide for the selection and application of various types of high-temperature conductors

Estimated 2012 Program Funding

$8.0M

Program Manager

Fabio Bologna, 704-595-2590, fbologna@epri.com
## Summary of Projects

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<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P35.001</td>
<td>Overhead Transmission Line Inspection and Assessment Methods Guideline</td>
<td>This project is a mix of tools, training, and information that will help members improve their inspection and assessment techniques.</td>
</tr>
<tr>
<td>P35.002</td>
<td>Conductor, Shield Wire and Hardware Corrosion Management</td>
<td>This project identifies, develops, and assesses tools and procedures required to deal with conductors, shield wires, and hardware exposed to atmospheric corrosion.</td>
</tr>
<tr>
<td>P35.003</td>
<td>Structure and Foundation Corrosion Management</td>
<td>This project helps determine cycle times for re-inspecting assets and the best methods of mitigating and remediating corrosion damage.</td>
</tr>
<tr>
<td>P35.004</td>
<td>Compression Connector Management</td>
<td>This project provides a holistic approach to the inspection and management of compression connectors.</td>
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<tr>
<td>P35.005</td>
<td>Crossarm and Composite Pole Management</td>
<td>Research is primarily focused upon assessing inspection technologies for crossarms and developing reject and ranking criteria for various construction materials.</td>
</tr>
<tr>
<td>P35.006</td>
<td>Lightning Performance of Transmission Lines and Surge Arresters</td>
<td>This project is a mix of tools, training, and information that will help members improve their transmission line lightning performance.</td>
</tr>
<tr>
<td>P35.007</td>
<td>Transmission Line Design Tools</td>
<td>This project will pursue the following activities:</td>
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<tr>
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<td>- Upgrade modules in the TLW-GEN2 software program and investigate new line design modules for inclusion one at a time.</td>
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<td>- Update and expand these modules to reflect changes that have occurred since they were last revised.</td>
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<td>- Review information in the Red Book that requires revision to enable members to take full advantage of the research results.</td>
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<td></td>
<td></td>
<td>- Conduct a workshop for technology transfer.</td>
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<tr>
<td>P35.008</td>
<td>Foundation Design and Research</td>
<td>This project develops a comprehensive design manual to assist foundation designers in evaluating, selecting, and designing cost-effective foundations suitable for single pole, H-frame, lattice tower, and guyed-V structures. A practical reliability-based design approach is first developed. Specific and practical topics such as specification for sub-surface investigation are to be developed and added to the manual until all key topics are covered.</td>
</tr>
<tr>
<td>P35.010</td>
<td>Live Working Research for Overhead Transmission Equipment, Techniques, Procedures and Protective Grounding</td>
<td>This project develops tools, procedures, and training materials for live and de-energized work to enhance worker and public safety, work efficiency, and reduction in cost and duration of maintenance outages.</td>
</tr>
<tr>
<td>P35.011</td>
<td>Polymer and Composite Overhead Transmission Line Components</td>
<td>This project addresses the use and maintenance of composite transmission line components. Through this project, members learn how to select, install, inspect, and maintain composite transmission line components used throughout the world.</td>
</tr>
<tr>
<td>P35.012</td>
<td>Ceramic Insulator Integrity Assessment</td>
<td>This project focuses on how to assess the aging population of porcelain and glass insulators, and how to properly procure and apply new and replacement insulators.</td>
</tr>
<tr>
<td>Project Number</td>
<td>Project Title</td>
<td>Description</td>
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<tr>
<td>P35.013</td>
<td>Increased Power Flow Guidebook and Ratings for Overhead Lines</td>
<td>This project provides state-of-the-science reference and training materials for optimizing and increasing power flow through transmission lines and entire transmission circuits. It also provides software tools to optimize power flow in real-time, for predictive assessments of power capacities, and for performing off-line rating studies.</td>
</tr>
<tr>
<td>P35.014</td>
<td>High Temperature Operation of Overhead Lines</td>
<td>This project will collect all available information on high-temperature operations, conduct laboratory tests to address knowledge gaps, and prepare software to facilitate risk evaluations of high-temperature operations. The project addresses the impact of high-temperature operations on the mechanical, electrical, and thermal behavior of overhead lines.</td>
</tr>
<tr>
<td>P35.015</td>
<td>Performance and Maintenance of High-Temperature Conductors</td>
<td>This project addresses all outstanding issues related to high-temperature conductors, one at a time. It will investigate the long-term performance of all commercially available advanced conductors to complement the field demonstration project, which provided information on handling and stringing these conductors. Maintenance tools and procedures for this new type of conductor will also be identified and established. A comprehensive guide for the selection and application of high-temperature conductors will be prepared.</td>
</tr>
<tr>
<td>P35.016</td>
<td>New and Emerging Inspection and Sensing Technologies</td>
<td>This project documents the latest inspection and sensing technologies for overhead transmission lines, as well as early adopters experiences with these technologies. Test results and demonstrations help members make more informed decisions when deciding whether to deploy such technologies.</td>
</tr>
<tr>
<td>P35.017</td>
<td>Design and Construction - Approach and Practices</td>
<td>This research develops a comprehensive, single source guide for the coordination of design and construction practices. Overhead line designs may be optimized to allow good construction practices while construction practices will be developed for new designs that requires unique or new approaches.</td>
</tr>
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**P35.001 Overhead Transmission Line Inspection and Assessment Methods Guideline (052001)**

**Key Research Question**
Utilities need research results on overhead transmission line inspection and assessment methods for several reasons. The current transmission infrastructure is aging, and it is important to keep it both reliable as well as extend its life. To do so, utility managers need to keep abreast of new inspection and maintenance practices, tools, and issues. If inspection and assessment of the transmission infrastructure is not thorough, the systems will eventually become less reliable, and components will fail. Without this understanding, utilities may not have a recovery plan in place when failures occur.

**Approach**
The Overhead Transmission research team recognizes the work processes and challenges of program members. This research project will employ a tiered approach that will develop a number of materials and then help utility workers quickly incorporate those materials into their everyday work routines. Application of the project's results should simplify their jobs and help them to do their jobs better. The research team:
- Develops and documents an understanding of indicators or symptoms of component degradation failure and inspection technologies in the Inspection and Assessment Methods (IAM) Reference Guide, the *Yellow Book*.
- Develops computer-based instruction systems to help in learning about assessments, technologies, and components.
• Develops field guides for field personnel that help identify and provide information on the state of a specific component and the action to take if it is compromised.
• Develops and documents an approach to transmission line faults investigation and analysis.
• Develops and hosts hands-on workshops and conferences where inspection and assessment information is disseminated.
• Develops and maintains failure databases of line components such as connectors and crossarms.

Impact
This research project may affect operations and benefit the public in a number of ways:
• These tools should help improve the reliability of power delivery components.
• The inspection and assessment process should be enhanced.
• The public should get more reliable power delivery.
• Public safety issues may arise if a component fails. With tools and techniques to help prevent component failures, safety can be enhanced in areas where the public live and play.
• Hands-on events can help improve utility workers’ skill sets by training members on inspection methods, available tools, and identification of high-risk components before they fail.

How to Apply Results
The research program is structured so the tools are ready to be incorporated into a member’s standard procedures. Members will be able to supply field guides to their field inspectors. Managers can use guides to set up their assessment programs. Hands-on training can provide staff with knowledge that they can apply immediately in the field. Computer-based training can be used throughout all levels of the organization, including field personnel and managers, as they apply what they learn from the Yellow Book reference material.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tr>
<td>This guide helps members initiate a new overhead transmission line inspection and assessment program or refine an existing one. It focuses on degradation of line components, and procedures and technologies for inspecting and assessing components. Additional material will be added to the guide.</td>
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<tr>
<td>New Pictorial Guide: These field guides are designed for field use both in electronic format and in pocketbook size (8 by 4 inches). Many members are distributing these guides to all field personnel, and the guides are forming the backbone of these companies’ inspection program.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Future On–line E–Learning Module: Online self–paced learning modules will continue to be developed around components or inspection technologies. These can be used on a desktop computer or with members’ current learning management systems.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td>Proceedings of the Biannual Overhead Transmission Lines Conference: The proceedings of the biannual Overhead Transmission Lines Conference will be compiled into a technical update. Various new inspection technologies, applications, and utility use cases may be presented at the conference.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Approach to Transmission Line Fault Inspection and Analysis (Draft): This product will build on research conducted in prior years and will document the approach and technologies for locating line faults, including their accuracy.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>New version of OHTL Inspection and Assessment Methods (IAM)</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Reference Guide (Yellow Book):</strong> This guide helps members initiate a new overhead transmission line inspection and assessment program or refine an existing one. It focuses on degradation and inspection of line components, and procedures and technologies for inspecting and assessing components.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Future On-Line E-Learning Module: Online self-paced learning modules will continue to be developed around components or inspection technologies. These can be used on a desktop computer or with members' current learning management systems.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td>Approach to Transmission Line Fault Inspection and Analysis: This product will build on research done in prior years and will document utility experience (approach, technologies and lessons learned) in locating line faults</td>
<td>12/31/13</td>
<td>Technical Update</td>
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P35.002 Conductor, Shield Wire and Hardware Corrosion Management (063280)

Key Research Question
Atmospheric corrosion is a natural and unavoidable phenomenon that can lead to premature failure of conductors, shield wires, hardware, or components and result in momentary or even sustained outages. The primary environmental factors controlling the occurrence and severity of this corrosion are airborne salts, acid rain, and time of wetness, but of equal importance are the initiation mechanisms for the protection systems such as galvanizing. Understanding this timeline allows utilities to establish inspection cycles based upon levels of risk, provide a population assessment utilizing new tools or techniques, and develop O&M budgets tied to corresponding maintenance practices.

Approach
This project provides tools and processes for inspecting and assessing overhead shield wires, conductors, and hardware. It also produces management and engineering guides, and provides guidance to asset managers. The project’s goals will be achieved via research in inspection, selection, application, and population assessment of phase conductors and shield wires and a hardware management program. The following are tasks underway:

- Development of a Near Infra-red (NIR) Spectroscopy Remote Inspection Tool to locate conductors with various levels of corrosion byproducts deposited on the conductor and structure or hardware surfaces.
- Understanding corrosion rates on test specimens and the associated tensile strengths. A corrosion laboratory has been developed in Charlotte to study the effects of the environment on corrosion rates for conductors and hardware in atmospheric service. Exposure testing of these components will help quantify those areas and allow utilities to establish inspection cycles based upon actual corrosion rates and allowable sectional losses.
- Replicate conditions needed for contractors and service providers to demonstrate and test new and emerging inspection and assessment technologies. Flaws are installed with specific sectional losses, and inspection methods are evaluated in the context of accuracy, cost, risk, and probability of locating damage.
- Population assessment methods based upon environmental factors and material exposure.
- Workshops to disseminate research findings, technology demonstrations and hands on training for inspection and assessment techniques.
Impact
The project will help reduce unplanned outages, improve reliability, and reduce associated repair costs by providing corrosion control and management practices for overhead ground wires, phase conductors, and hardware. It could also provide a more accurate picture of the status of the power delivery infrastructure, enabling more informed maintenance and fiscal decisions.

How to Apply Results
Transmission designers, engineers, operators, asset managers and inspectors will use the results of this project to inspect and assess overhead shield wires and conductors. Employing the knowledge gained from the project's results will help members develop a cost-effective maintenance program that will improve reliability by identifying and assessing high-risk shield wires and conductors prior to failure.

2012 Products

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<tbody>
<tr>
<td><strong>Inspection and Assessment of Overhead Transmission Line Hardware (Draft):</strong> This technical update will document the current state of industry inspection methods and examine new and emerging technologies for identifying corroded conductors and hardware.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>NIR Spectroscopy Development and Alternate Technology Uses:</strong> This product is the continuation of the NIR spectroscopy technology development and other structural inspection applications.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Member Survey of Industry Issues for Hardware and Conductors:</strong> A survey designed to highlight potential pending issues concerning atmospheric corrosion on hardware exposed to the environment.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>State of the Art Field Evaluation Methods for Galvanize Coatings:</strong> Field evaluations of galvanizing coating systems are varied and sometimes subjective. This technical update is designed to allow field personnel and technicians to understand and quantify galvanize coatings in the field with minimal equipment requirements and training.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Inspection and Assessment of Overhead Transmission Line Hardware (Final):</strong> Trending for corrosion has always been the most accurate method for targeting O&amp;M budgets. This product may help identify areas more prone to corrosion issues that could allow members to focus on pending issues and be proactive in avoiding costly outages.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Inspection Optimization and Environmental Factor Modeling With GIS Overlays:</strong> System modeling using existing government data and optimization by converging inspection results will allow a better understanding of the environment and its role in corrosion issues.</td>
<td>12/31/13</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Understanding Galvanizing Life, Degradation Modes and Inspection Methods:</strong> Inorganic protective coatings are applied in the molten state and can be subject to many issues when not properly processed. In addition to manufacturing issues, there are many environments where galvanized surfaces should not be installed. This research provides an overview of the metallurgy, the degradation modes, and a method to determine the effectiveness of the remaining galvanizing system.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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</table>
P35.003 Structure and Foundation Corrosion Management (063281)

Key Research Question

The total cost of corrosion to U.S. industry is more than $276 billion annually, of which more than 30% could be prevented through the use of optimum corrosion-management practices. Even within the electricity industry, the costs associated with corrosion range from $5 billion to $10 billion each year. Transmission and distribution lines are also greatly affected by the effects of sub-grade corrosion. These effects are manifest in costly outages and increased O&M costs. Visual inspection by excavation is the predominant method of inspection, but this process is costly and labor intensive. Thus, research is needed to provide members with methods for effective sub-grade corrosion management.

Approach

This project addresses the issues surrounding corrosion of transmission line structures by providing O&M staff with tools and techniques to make the most informed and cost-effective decisions. Improved corrosion management will be achieved through developing and refining inspection techniques and methodology, informing assessment practices, and creating effective remediation techniques. This project will culminate in the production of a comprehensive corrosion management program, with the ultimate goal of reducing total O&M costs associated with structure and foundation corrosion. The following core tasks are underway:

- Assessment of commercially available coating systems to understand corrosion initiation mechanisms and cycle time for future inspections.
- Replication of conditions on test specimens at the EPRI outdoor test facilities to characterize the performance of different inspection technologies and mitigation methods provided by vendors.
- Evaluation of inspection and assessment techniques dedicated to anchor rod inspections.
- Evaluation of inspection and assessment technologies for tubular structures.
- Evaluation of inspection and assessment technologies for lattice structures with grillage foundations.
- Development of electrochemical test techniques to measure corrosion rates on structures and grounding systems in situ, which will prioritize service areas and allow the development of inspection cycles for lattice and pole populations.
- Understanding corrosion rates on test specimens through soil exposure testing at the EPRI corrosion laboratory will allow an understanding of the environmental factors occurring within members’ service areas. These tests are designed to quantify the effects of these factors on the corrosion kinetics and help design mitigation methods to arrest the corrosion.
- Research and development of cathodic protection systems for the internal surfaces of tubular structures.
- Future workshops to provide education and hands-on training for inspection, mitigation, and remediation techniques.

Impact

This program will:

- Reduce outages by understanding the life cycle of various structure types.
- Provide new tools and inspection methods to address structure and foundation corrosion problems.
- Defer inspection and replacement costs by understanding the features and benefits of new and emerging inspection, mitigation, and remediation technologies.
- Reduce O&M costs by matching cycle times with mitigation and remediation techniques.
- Help engineering to reduce the probability of corrosion that may occur in new construction.
How to Apply Results

Transmission operations and maintenance staff will use the tools and knowledge delivered in this project to develop a cost-effective maintenance program to inspect, assess, and refurbish structure and foundation infrastructure, and consequently extend its life. This program may improve reliability by identifying and assessing high-risk sub-grade components prior to failure.

2012 Products

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<tr>
<td>Coating Assessment - Continuing: Started in 2008 with the development of a coating assessment protocol, EPRI reviews and evaluates the performance of new and emerging coating systems. This evaluation takes into account the service conditions and exposure to environmental factors to understand the strengths and weakness of each system. A review of these coating characteristics allows utility personnel to match their structure needs to the appropriate coating system and optimize their O&amp;M budgets.</td>
<td>12/13/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Evaluation of New and Emerging Corrosion Sensors: This product will evaluate new or existing corrosion sensors and identify new concepts to quantify the kinetics governing corrosion rates. This environmental data will then be correlated with the associated corrosion rates measured through electrochemical and mass loss techniques. The long-term plan is to monitor system degradation (corrosion) through trending.</td>
<td>12/13/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Structural Repair Methods for Lattice Structures &amp; Grillage Foundations: The last aspect of inspection and assessment programs is how the structure is returned to its original condition at the time of installation. This technical update highlights available structural repair methods and the caveats associated with each method.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Mitigation Methods for Tubular Structures (Draft): This product will highlight the development of tools required to protect the internal surfaces of tubular structures. Studies have shown that traditional cathodic protection systems will not provide sufficient passivation to prevent the formation of corrosion cells on internal surfaces of the poles, and a high percentage of poles have standing water inside.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Corrosion Probe Development (Draft): This product summarizes the development of a corrosion probe that is designed to measure the effects of the environment on specific materials used in the construction of the structure, foundations, and grounding system. Corrosion rates may be obtained by using electrochemical polarization resistance or impedance spectroscopy tests on specimens of various materials that are connected to the structure during the evaluation.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Inspection, Assessment and Remediation Methods for Concrete Foundations: There are many accepted passive and active half-cell techniques that will allow an understanding of reinforcing steel condition within concrete. This technical resource will provide a hands-on understanding of how to apply these electrochemical inspection techniques and what technologies are available to restore the condition of the concrete.</td>
<td>12/31/13</td>
<td>Workshop, Training, or Conference</td>
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</table>
Mitigation Methods for Tubular Structures (Final): The potential for corrosion on the inside of a tubular structure was unknown until recently. Cleaning issues before the galvanizing operation have resulted in premature structural failures and that has alerted the industry to the need for advanced mitigation techniques. This product is focused upon potential methods or techniques to deliver and apply uniform sacrificial anode, cathodic protection to the internal surfaces of a tubular structure.

Field Methods for the Evaluation of Concrete Structures and Foundations: This is a field guide that summarizes the best-in-class inspection techniques and how to interpret the findings. Included with this guide are visual coupons for comparison and the remediation or mitigation methods most appropriate as a corrective action.

Inspection and Assessment State of the Art Report (Draft): This deliverable is the summary report of past evaluations of inspection techniques and technologies. Included are new and emerging methods of inspection with an assessment of accuracy, potential for finding corrosion, risk, and cost of implementation.

P35.004 Compression Connector Management (065547)

Key Research Question

Predicting the remaining life of compression connectors (splices and dead-ends) is a major challenge. Compression connector failures are expected to increase with increased demand for heavier loading operations. Due to the limitations of existing inspection techniques, isolating the components early enough to avoid failure is difficult. Inspection techniques and population evaluation methodologies are needed.

Technologies currently used to inspect compression connectors are not always reliable and repeatable, and application methods and threshold levels for these technologies are not well defined. This project will increase understanding of the currently available techniques, their performance, and their application. Guidelines will be provided for their application, and promising new techniques will also be sought and identified.

The performance of compression connectors is directly related to installation practices and procedures. Conductor cleaning and field personnel training remain two key priorities to address these issues.

Approach

This project addresses the issues surrounding inspection, assessment, and remediation of compression connectors by providing O&M staff tools and information to make the most informed and cost-effective decisions.

Field Guide for the Inspection of Compression Connectors: In 2010 and 2011, EPRI undertook a study to determine temperature threshold limits for inspecting compression connectors using infra-red imaging. In 2012, this work will be documented in the form of a visual field guide. The field guide will provide guidance on factors to consider when doing a field inspection.

Online Training Module: EPRI will develop a training module for field personnel on the installation, maintenance, inspection, and remediation of compression connectors. The training will detail the latest inspection technologies, as well as present best practices for the use of existing inspection technologies and connector installation.
Evaluation of New Technologies: EPRI will continue to evaluate new and emerging technologies that could be used for determining the condition of compression connectors. This work could include the improvement of existing technologies, the development of new technologies/devices, as well as the application and evaluation of nontraditional compression connector inspection techniques.

Failure database: Continued maintenance of compression connectors failure databases (ongoing since 2009) to aid in selection and replacement decisions.

Impact
This research project may affect members' operations in a number of ways:
- Increase safety of transmission lines by reducing line dropping
- Reduce sustained unplanned outages due to compression connector failure
- Optimize spending of O&M funding
- Improve productivity of field personnel with training and field tools
- Address the loss of institutional knowledge by providing training.

How to Apply Results
Members will modify their current inspection practices as a result of the research. Operations and maintenance personnel can implement the developed EPRI population assessment methodology. Field personnel will be able to use the provided workshop training material as part of their in-house training programs.

2012 Products

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<tr>
<td>Online Training Module on Inspection Techniques and Evaluations: A computer-based training module will be developed that details inspection techniques and evaluations. This software will be able to be used with members' current learning management systems.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td>Field Guide: Inspection Techniques and Evaluations: A field guide for personnel will be prepared with inspection tools and techniques as evaluation considerations for compression connectors.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Evaluation of New Inspection Technologies and their Application: This task will evaluate promising new inspection technologies. These technologies will be tested and evaluated to determine feasibility as an inspection technology.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Connector Failure Database: Information on connector failures received from utilities will be analyzed and trends determined. This will enable the identification of future areas of research.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P35.005 Crossarm and Composite Pole Management (067437)

Key Research Question
Predicting the remaining life of structural crossarms and composite poles is a major challenge to electric utilities because of limited inspection techniques that align with that type of component. Degradation must be identified early enough to avoid failure and allow maintenance groups sufficient time to anticipate and plan for replacement or remediation operations. Improved inspection techniques and population evaluation methodologies are needed to support this effort or an increase in crossarm failures can be expected as transmission structures age.
The application of composite materials used in the construction of crossarms and poles needs extensive research through exposure testing and forensic studies, because little is known of the degradation modes and initiation mechanisms. Effects due to electric field exposure, airborne particulates, and aerosols will be included in this study so that the limitations and applications can be better understood.

The cost and physical performance of crossarm assets are directly related to inspection practices and decisions. Identification of crossarm degradation and timely replacement decisions by field personnel remain two key priorities.

**Approach**

This multiyear project addresses a range of crossarm and pole concerns, including selection, application, and inspection to increase members' confidence in using these materials of construction. In 2009, the project focused on the degradation modes of dimensional lumber crossarms and the existing tools and techniques available for inspection and assessment programs. In 2010, a test jig was designed, developed, and constructed in Charlotte to facilitate the assessment of inspection technologies. Building on that foundation, future project activities include:

- Desk study on composite materials, manufacturing methods, and contraindications in the construction and use of composite crossarms and poles.
- Evaluation of existing inspection and assessment tools for wood/composite crossarms and poles.
- Development of new and emerging technologies for laminated crossarms with the associated features/benefits.
- Field guide to aid maintenance personnel in the inspection and assessment of laminated wood crossarms.
- Development of a crossarm failure database to track failures by material, age, size, type of construction, and environmental factors will provide invaluable information for inspection program optimization.
- Evaluation and development of remediation techniques for wood and composite crossarms and poles.
- Population assessment methods based upon environmental factors, initiation mechanisms, and failure modes.
- Remediation techniques for steel crossarms.
- E-learning module for field personnel training.

**Impact**

This project may have the following impacts:

- Increase safety of transmission lines by reducing crossarm failures
- Understand the application and inspection of composite pole structures
- Reduce sustained unplanned outages attributable to crossarm failures
- Address loss of institutional knowledge by providing training
- Optimize spending of O&M funding
- Improve productivity of field personnel with training and field tools.

**How to Apply Results**

Members will modify their current inspection practices as a result of the research focused upon inspection and assessment of crossarms. This project improves the expertise of the workforce and addresses the loss of knowledge in the industry. The project may culminate in reliability improvements by identifying and assessing high-risk components prior to failure. Operations and maintenance personnel can implement the developed EPRI population-assessment methodology themselves or as part of a supplemental project.
2012 Products

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<tr>
<td>Member Survey on Steel Crossarms: The number of failures attributed to corrosion or the number of crossarms that are taken from service are unknown. This survey will afford us a better understanding of what issues are on the horizon and provide guidance for further degradation mode research.</td>
<td>12/13/12</td>
<td>Technical Update</td>
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<tr>
<td>Degradation Modes of Composite Crossarms and Poles, Desk Study: This research is designed to understand environmental and operational factor effects on the performance of composite materials. Included are electric field effects, the effects of ultraviolet light, and pollutants such as sulfates or chlorides. As composite materials age, it becomes necessary to determine degradation rates and modes of failure based upon construction standards.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Evaluation of Member Supplied Crossarms and poles: This product will provide an understanding of failure modes and initiation mechanisms of construction materials in various types of applications. Project-member-supplied components will be tested and analyzed at the EPRI facilities. The results will be provided to project members so that a better understanding of the material limitations may be shared and disseminated.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>E-learning Module on Crossarm Inspections and Evaluation: A online training module will be developed to train field personnel in failure modes, inspection tools, and techniques as evaluation considerations for crossarm inspection.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td>Evaluation of Composite Crossarm and Pole Inspection Methods: Evaluation methods for composite materials differ from wood and steel construction. This can be attributed to the material properties but also the failure modes. This research quantifies new and emerging inspection technologies or techniques in terms of accuracy, risk, probability of locating degradation, and cost of implementation.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Field Guide on Crossarm Inspections and Evaluations: A field guide for field personnel will be prepared covering the failure modes, inspection tools, and techniques as evaluation considerations for crossarm inspection.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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P35.006 Lightning Performance of Transmission Lines and Surge Arresters (051989)

Key Research Question

Lightning activity is the leading cause of momentary outages on transmission lines. Addressing numerous aspects of a transmission line—shielding, grounding, insulation, and transmission line surge arresters—can improve lightning performance. However, identifying the most effective and lowestcost aspects is difficult. Transmission line grounding influences both the lightning performance and safety of transmission lines, and the most effective ground electrode design depends on a variety of factors.
**Approach**

The tasks addressed in this project set are:

**Lightning Performance Prediction Software (TFlash Module):** In 2011, TFlash was integrated into the Transmission Line Workstation Generation 2 (TLW-Gen2) software as a module. In 2012, the TFlash module will be expanded from only performing lighting performance calculation to include the calculation of structure currents under fault conditions. Participants in this project will get access to the TFlash module of TLW-Gen2.

**Field Tool to Evaluate Transmission Line Grounds (EPRI Zed-Meter®):** Commercial ground electrode measurement techniques do not accurately measure structures that are grounded in multiple locations, such as transmission lines with overhead ground wires, steel lattice structures with grillage foundations, and two-pole structures. From 2004 to 2011, a technology that enables effective measurement of transmission line ground electrodes was developed and demonstrated, and an application guide was developed. In 2012, research will focus on adding additional functionality such as soil resistivity to the instrument.

**Transmission Line Surge Arrestors (TLSA) Research:** This task develops information resulting in a TLSA application guide. In 2009, the first version of a guide was completed, and in 2010, an application workshop based on the guide was held. In 2011, a review of current knowledge on gapped line arrestors was done. In 2012, current disconnector standards will be reviewed, and applicable test methods and gaps identified. Evaluation of units removed from service and the TLSA failures database will be continually updated.

**Grounding:** Companies are currently struggling with issues surrounding copper theft, electrode corrosion and sizing of OPGW. This task will investigate the use of alternative materials, electrode designs and provide guidance on the sizing OPGW. Issues such as design practices, life expectancy, corrosion, material compatibility, and current-handling capabilities will be addressed.

**Improved Quantification of Lightning Detection Networks:** In 2011, a document comparing the lightning data provided by three lightning location networks in the United States was developed. In 2012, an understanding of the accuracy and limitation of the information provided will be documented. Results could help enhance the usefulness of lightning detection information.

**Impact**

This project may have the following impacts:

- Improve lightning performance and safety of transmission lines by providing engineers with effective tools and an improved knowledge base.
- Address the loss of institutional knowledge by providing guides and tools for engineering staff who are new to the field of lightning and grounding.
- Reduce costs by providing improved tools (e.g., Zed-Meter and TFlash) for both field inspection and engineering staff.
- Improve public and worker safety, as well as transmission reliability, by identifying alternative ground electrodes.

**How to Apply Results**

Operations and maintenance personnel can apply the EPRI Zed-Meter to measure the tower footing resistance of structures on their systems. Transmission line engineers can use the lightning performance prediction software to optimize the lightning performance of transmission lines with internal resources, or can outsource this work to the EPRI Lightning and Grounding Team. Information on TLSAs will provide design and O&M maintenance personnel with knowledge on the application and inspection of TLSAs.
## 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Evaluate the performance of new and current Lightning Detection Networks:</strong> There are new and currently operated sensor (network) technologies that have undergone technical upgrades over the past years. Utilities are interested in understanding the type and accuracy of the information provided. This product will compare utility lightning fault data with lightning data currently delivered by those systems.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Sizing of Overhead Ground Wires with Respect to Lightning:</strong> Traditionally, steel conductors have been used for overhead ground wires, but increasing OPGW is being used. These newer ground wires may not be as tolerant to direct lightning strikes, and therefore, dimensioning with respect to lightning currents is becoming increasingly important. This product will document an approach for dimensioning these conductors.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Transmission Line Workstation (Gen2) Ver 1: TFlash module update:</strong> The TFlash module will be updated to include the calculation of structure currents under fault conditions.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Investigate methods to determine corrosion of ground electrodes:</strong> This product will document the current inspection methods and examine new and emerging technologies for identifying corroded ground electrodes.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Review of TLSA Disconnectors Specifications:</strong> This deliverable will review applicable test methods for disconnectors. Aged disconnector units will be collected from member utilities for future testing. In future years, these results will be analyzed and refined to develop tests and specification requirements.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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## Future Year Products

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<tr>
<td><strong>Transmission Line Workstation (Gen2): TFlash Module update:</strong> A feature to estimate soil parameters will be added to the TFLash module in TLW (Gen2). This feature will enable the user to derive a two-layer soil model from one or more measured soil resistivity profiles. Multiple profiles can then be compared to choose an appropriate soil model for calculating the ground electrode resistance.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Document Use Cases for Lightning detection networks:</strong> Working with a member utility, EPRI will assess the performance of National Lightning Detection Network (NLDN) data by identifying and correlating flashes with transmission line events.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Calculation of Structure Currents Under Fault Conditions:</strong> When a fault occurs on a line, the fault current divides between the OHGW, the ground leads, and ground electrode. The division of current needs to be known to a) Calculate the size of the grounding conductors, and b) Calculate the prospective Ground Potential Rise (GPR) along the line. The methodology to calculate the current division and structure GPRs will be documented.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Transmission Line Surge Arrestors: In-service Inspection Technologies:</strong> There is a need to determine the in-service condition of TLSA’s. Existing methods include detailed visual inspections, inspections using infra-red imaging, and direct measurement of leakage current through the zinc oxide blocks. This product will provide an update on available and emerging technologies and how they are applied.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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</table>
P35.007 Transmission Line Design Tools (060457)

Key Research Question

In 2010, EPRI developed an alpha version of the TLW-GEN2 software package. The TLW-GEN2 software is a program that integrates the user interface and data of a collection of software tools that are used for line design or performance evaluation purposes. TLW-GEN2 intends integrates all of the EPRI design software into a single package and enables easier importing from packages such as PLS-CADD. In 2011, the ACDCLine and TFlash modules were added to the package. Each year new modules may be added to the TLW-Gen2 software package, or existing modules may be upgraded, based on the latest available technical information. Furthermore, in order to take advantage of the most current research results that have become available since the 3rd Edition of the Red Book was published in 2005, chapters of the Red Book will also be updated.

Approach

The project continues to develop and upgrade EPRI design software of interest to the members for inclusion in TLW-GEN2. Improvements and updates to the ACDCLine module (which is to be released as an beta Version in 2011) are to be made. An improved final version of ACDCLine module of TLW-Gen2 will be delivered in 2012.

Further in 2012, the Aeolian vibration software for single overhead conductors will be reviewed, upgraded, and brought into TLW-GEN2. A beta version of the software with extensive testing and input from members will be completed by the end of the year. The software will be finalized in the following year. By the end of 2012, the final version of ACDCLine and a beta version of Single-Conductor Vibration software will be available in TLW-GEN2 under this project. Other design software packages to be selected by members will be brought into TLW-GEN2 in future years.

In addition, one of the chapters of the Red Book will be updated and revised starting in 2012. Revision of the Red Book will be carried out continuously, chapter by chapter. The number of chapters to be revised each year may be adjusted according to the needs of the members and funding available for the year. The updated Red Book will be available in electronic format.

Impact

This project may have the following impacts:

- Help designers select optimal transmission line design parameters and designs
- Improve designer productivity
- Improve overhead transmission line reliability
- Reduce maintenance and repair costs

How to Apply Results

The TLW-Gen2 provides an efficient and effective tool to help overhead line engineers design lines. It allows designers to evaluate different aspects of designs—electrical, mechanical, and others—without duplicating input data. Because all the modules have the same look and feel, TLW-GEN2 will improve the productivity of the designers when using different modules. The new ACDCLINE module will be extended to analyze the electrical effects of DC lines.

Members can take advantage of the most current information available in the revised Red Book which has been a core reference for transmission line engineers for decades.
2012 Products

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<tbody>
<tr>
<td><strong>TLW-GEN2: ACDCLine Module &amp; Single-Conductor Vibration Design and Control Module - Beta Version:</strong> The existing software for the design and control of single-conductor vibration will be reviewed, updated, and upgraded for new features. The user interface will be improved to facilitate the use of the software. A beta version of the software will be available as a module in the TLW-GEN2 software package and is to be extensively tested by users. By the end of 2012, the final version of ACDCLine and a beta version of Single-Conductor Vibration software will be available in TLW-GEN2 under this project.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
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</table>

| **Updated Red Book - One New Chapter:** One chapter of the Red Book will be updated. The chapter with the most outdated information will generally be chosen for the year. Input from members will be sought for the final decision. The updated Red Book with one new chapter will be available in electronic format. | 12/31/12 | Technical Update |

Future Year Products

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<tr>
<td><strong>TLW-Gen2: ACDCLine Module &amp; Single-Conductor Vibration Design and Control Module:</strong> The software for the design and control of single-conductor vibration will be finalized. By the end of 2013, the final version of ACDCLine and the final version of Single-Conductor Vibration software will be available in TLW-GEN2 under this project.</td>
<td>12/31/13</td>
<td>Software</td>
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| **Updated Red Book - An Additional New Chapter:** One chapter of the Red Book will be updated. The chapter with the most outdated information will generally be chosen for the year. Input from members will be sought for the final decision. The updated Red Book with two new chapters will be available in electronic format. | 12/31/13 | Technical Update |

| **Updated Red Book - An Additional New Chapter:** One chapter of the Red Book will be updated. The chapter with the most outdated information will generally be chosen for the year. Input from members will be sought for the final decision. The updated Red Book with three new chapters will be available in electronic format. | 12/31/14 | Technical Update |

| **Addition of a Design Module in TLW-GEN2:** An extra module for overhead line designs will be integrated into the TLW-GEN2 software package. The module that is to be included will be decided upon based on member input. The new module will be in addition to the existing ACDCLine and Single-Conductor Vibration software modules. | 12/31/14 | Software |

P35.008 Foundation Design and Research (067438)

**Key Research Question**

New transmission lines are required to meet increasing demand of electric power and to improve system reliability. The foundation for an overhead line structure is a major component of the transmission line. An improperly designed foundation could be costly and unreliable and may require high maintenance. A reliable overhead line requires properly designed foundations that are compatible with the surrounding soil. The uncertainty in the behavior of soil and the lack of soil information have made this compatibility challenging.
The objective of the project is to provide transmission line designers state-of-the-art tools for designing transmission structure foundations. Tools include design methods and associated assumptions, approaches, formulae, sample calculations, and data that are required to design structure foundations properly and efficiently.

The project provides the state-of-the-art information and design methods to assist foundation designers in evaluating, selecting, and designing foundations suitable for single pole, H-frame, lattice tower, and guyed-V structures.

Approach

The project started in 2009 with a review of current information on the design of transmission line foundations from publications, standards, and manuals such as those from the American Society of Civil Engineers, the Institute of Electrical and Electronic Engineers (IEEE), and the International Council on Large Electronic Systems (CIGRE). A survey was conducted among electric power utilities on the design of transmission structure foundations. The survey results established a common practice for the design of transmission structure foundations, such as typical strength and safety factors applied to computed nominal foundation capacities.

In 2010, an investigation was initiated of the reliability-based approach for transmission structure foundation designs, and a general guide for the reliability-based approach was developed. In 2011, specification for subsurface investigations for reliability-based designs, and methods to determine geotechnical design parameters between borings are being developed for inclusion in the guide. For 2012 and beyond, topics considered are: research various methods for designing rock anchors such as Micropile, develop mini-pile and helical anchor foundation designs, improve geotechnical data by taking new measurements or obtaining data from other industries, improve soil and rock correlation for geotechnical design parameters, conduct full-scale foundation testing to verify strength factors, and conduct full-scale laboratory bending tests of reinforced concrete drilled shafts to evaluate economic benefit of longitudinal steel in resisting shear stresses. The topics for each year will be prioritized and selected by members.

This project will take advantage of the knowledge gained in past research conducted by EPRI. The goal of the project is to produce a comprehensive manual using different approaches for the design of single-pole, H-frame, lattice tower, and guyed-V transmission structure foundations. The manual will bring a common foundation design practice to the electric power industry.

Impact

This project may have the following impacts:

- Provide state-of-the-art methods for designing transmission structure foundations
- Provide information to evaluate risks of certain types of foundation designs
- Avoid expensive maintenance and repair costs
- Improve and provide uniformity to overall transmission line reliability.

How to Apply Results

The project will provide members with the most current practices on foundation design for overhead lines. Transmission line foundation designers can use this information to fine-tune their own design practice to produce reliable, cost-effective transmission structure foundations. The knowledge transfer to members, especially those with less experienced staff, is enhanced by attending training offered under this project.
## 2012 Products

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<tbody>
<tr>
<td><strong>Workshop for Foundation Design and Analysis</strong>: A member workshop will be conducted on the design and analysis of transmission structure foundations, including theories, methods, and the application of software.</td>
<td>12/31/12</td>
<td>Workshop, Training, or Conference</td>
</tr>
<tr>
<td><strong>Transmission Structure Foundation Design Manual</strong>: A comprehensive design manual is to be prepared. New chapters based on topics selected by members that year are to be developed and added to the manual. The manual will cover basic theories, equations, specifications, data, different design approaches for various foundation types, and commonly available software for designing and analyzing transmission structure foundations. Case studies are included.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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## Future Year Products

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<td>Technical Update</td>
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## P35.010 Live Working Research for Overhead Transmission Equipment, Techniques, Procedures and Protective Grounding (051995)

### Key Research Question

Deregulation and the economic realities of today’s electric utility business are forcing utilities to ensure that transmission and distribution lines remain in service every day. Outages for maintenance are more difficult to obtain, and the associated congestion costs for taking lines out of service are becoming prohibitive. In search of solutions, transmission owners are increasingly turning to live-line working techniques as standard practice to perform required maintenance. Live-line work must be performed safely. Work on de-energized lines, when it is possible, still involves hazards that include step-touch-transfer and induced voltages. These hazards in de-energized work must also be recognized and mitigated. New techniques, tools, and procedures are needed for: work on high-temperature conductors, live work on HVDC lines, minimum approach distances for helicopters in...
energized environments, design of structures to facilitate safe, efficient, and economic execution of live work, energized rescue, and training of crews to promote safety during both energized and de-energized work, including such situations as construction in the vicinity of energized lines.

Live working under HVDC conditions is not as widely practiced as under HVAC conditions. This project will study and conduct tests to determine the best practices for HVDC live working. The Live Line studies in this project will be done jointly with the Live Line studies undertaken in Program 162. This arrangement will allow for shared resources, expertise, and results.

**Approach**

Over the past two decades, EPRI has helped many transmission companies achieve significant safety improvements and cost savings in the areas of live working and de-energized work by developing and implementing new technologies and training materials for maintaining and refurbishing transmission lines. The results of this effort were consolidated with industry practices into a comprehensive *Live Working Reference Book* (the *Tan Book*, 1018974) and the online Live Working Resource Center. Building on that foundation, project activities in 2012 will address specific issues in live and de-energized work. These activities will include:

- Robotic technologies for live working
- Live work with high-temperature conductors
- Ropes for live work and energized rescue
- Technology transfer through updating the Tan Book, training videos/DVDs, meetings, and webcasts
- Live work on HVDC lines

**Impact**

The impacts of this program can include:

- Increase worker safety
- Improve reliability and availability by enabling timely maintenance of transmission lines, both energized and de-energized
- Improve transmission performance
- Decrease maintenance costs
- Application of innovative ideas and tools, such as robotics to live work

**How to Apply Results**

Participation in this project will help overhead transmission owners, maintenance service providers and linemen improve safety and transmission performance, enhance reliability, and reduce maintenance costs by supporting worker safety when conducting live-line and de-energized maintenance on overhead transmission equipment, as well as through the development of new tools, equipment and procedures. New methods will be documented in written reports and the online Live Working Resource Center. Training materials will be developed in electronic media using live action videos, computer generated scenarios, and live narration.

**2012 Products**

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Robotic Technologies for Live Working:</strong> This product will continue the development, initiated in 2011, of robotized autonomous and semi-autonomous devices for live work, such as automated cotter key handler, remotely deployable portable protective air gaps and temporary grounding switches, and remotely controlled insulator string strain release robots. This product will also build on research performed in prior years on further adaptation of available and developing robotic technologies such as autonomous robots, programmable actuators, and various types of sensors and control algorithms to live work. A Technical Update report will be published.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
### LW with high-temperature conductors

**Title and Description:** This product will build on research performed in prior years and will address areas of concern regarding live work on conductors operating or designed to operate at high temperature, identify issues, and discuss optimal solution approaches and new live working tools that could help facilitate safe and efficient work on energized hot conductors. A Technical Update report will be published.

**Planned Completion Date:** 12/31/12

**Product Type:** Technical Update

### Ropes for live work and energized rescue

**Title and Description:** This product will continue research on ropes suitable for use in energized environments and will develop functional specifications for ropes for use in rescue operations from energized lines. Plans include testing of ropes and development of training materials and a field guide for energized rescue.

**Planned Completion Date:** 12/31/12

**Product Type:** Technical Update

### Update Chapters of the EPRI Live Working Reference Book

**Title and Description:** The EPRI Live Working Reference Book (the Tan Book, 1018974) was published in 2009. Since then, new materials and information have become available, and applicable revised standards have been published. This product will produce updated and new chapters of the Tan Book, for example: live work on HVDC lines, live work on friendly/unfriendly structures, transmission and substations arcflash issues, minimum approach distances for helicopter-based work, and live work on high-temperature conductors.

**Planned Completion Date:** 12/31/12

**Product Type:** Technical Update

### Future Year Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Training Materials for LW with high-temperature conductors:</strong> This product will build on the companion project on live work on high-temperature conductors, and will develop training materials on the subject.</td>
<td>12/31/13</td>
<td>Workshop, Training, or Conference</td>
</tr>
<tr>
<td><strong>LW friendly/unfriendly structures:</strong> This product will summarize work performed to date related to live work on friendly/unfriendly structures, and will develop training materials on the subject. The training materials will highlight issues that the maintenance crew should bring to the attention of the design team prior to completion of structure designs.</td>
<td>12/31/13</td>
<td>Workshop, Training, or Conference</td>
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<tr>
<td><strong>Training Materials for Live Work on HVDC Lines:</strong> In view of increased interest in high-voltage direct current (HVDC) systems, this project will build on the companion project on live work on HVDC lines in Program 162, and will develop training materials on the subject. This arrangement will allow for shared resources, expertise, and results.</td>
<td>12/31/14</td>
<td>Workshop, Training, or Conference</td>
</tr>
<tr>
<td><strong>Robotic Devices for Live and De-Energized Work:</strong> This product will continue the development, initiated in 2011, of robotized autonomous and semi-autonomous devices for live work, such as automated cotter key handler, remotely deployable portable protective air gaps and temporary grounding switches, and remotely controlled insulator string strain release robots. This product will also build on research performed in prior years on further adaptation of available and developing robotic technologies such as autonomous robots, programmable actuators, and various types of sensors and control algorithms to live work.</td>
<td>12/31/15</td>
<td>Hardware</td>
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</table>
Emerging Issues in Live and De-Energized Work above 800 kVAC and 600 kVDC:
Transmission systems at voltage levels above 800 kVAC and 600 kVDC have moved from research stage to construction and full operation. When these lines need to be maintained live, new tools and procedures must be developed, and new as yet unknown issues must be addressed. De-energized work near such lines also raises many new questions that have not been researched. This product will initially monitor live and de-energized issues on new lines operating at voltages above 800 kVAC and 600 kVDC, and in later years develop guidelines, tools, and training materials for linemen. Technical Update reports will be published periodically.

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<td>12/31/16</td>
<td>Technical Update</td>
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**P35.011 Polymer and Composite Overhead Transmission Line Components (051993)**

**Key Research Question**

Due to their reduced cost, ease of handling, improved contamination performance, and resistance to vandalism—as well as a lack of availability of traditional components—composite components such as polymer insulators are proliferating on the electricity system. These components, however, have certain disadvantages and uncertainties. This project will address a range of composite component concerns including selection, application, inspection and population assessment, and can help to increase member confidence and reliability in using these components.

**Approach**

This ongoing multiyear project addresses a range of composite component concerns and includes examination of composite components, such as polymer insulators, guy strain insulators, fiberglass crossarms.

Specific topics and tasks will be added and removed under the direction of the Insulator Task Force. Activities in 2012 include:

- Multistress accelerated aging test for polymer insulators, guy-strain insulators, fiberglass crossarms, and composite poles at 230 kilovolts (kV). A full evaluation of the composite components will be performed and compared to previous evaluations of in-service units. A web browser report of the inspection results of the multistress accelerated aging test will be delivered.
- Development of short-term tests to evaluate the performance of composite components, including life expectancy. The intention is that utilities will include these tests in their specifications.
- Continued maintenance of polymer insulator and fiberglass components failure databases (ongoing since 1997) to aid selection and replacement decisions.
- Continued assessment of service-aged insulators and maintenance of an inspection database result in an understanding of how insulators age and how to validate the aging chamber.
- Development of a software tool (EPIC) to calculate E-fields to aid in the correct selection of corona rings for different applications.
- Development of a protocol to assess an in-service population of polymer insulators to make informed decisions on replacement.
- Develop plans to evaluate the corona threshold on end fitting seals, evaluate corona ring use and durability, and assess life expectancy of corona damaged insulators.
- Starting in 2012, an insulator book will be developed based on existing EPRI material and new research findings. The Book will be updated and revised continuously, chapter by chapter. The number of chapters to be revised/updated each year may be adjusted according to the needs of the members and funding available for the year. The Book will be available in electronic format.
Impact

The project may have these impacts:
- Reduce construction costs and improve performance by correctly applying composite components
- Avoid sustained outages by improved methods for inspecting and assessing both individual and populations of insulators
- Help members develop effective specifications, ensuring long-term performance of composite components
- Improve engineer productivity by providing information and tools.

How to Apply Results

- Engineers will use the multistress aging test results to assess existing populations of composite components and evaluate different composite component designs.
- The failure database information will help evaluate aging populations of units and selection of new designs.
- The inspection of service-aged insulators will aid in understanding how insulators age and the factors of aging. Members can use this information to improve applications for improved reliability and performance.
- The Corona Ring Selection Software Tool is used when designing new applications and evaluating the performance of existing applications in service.
- Either members or EPRI can use the population assessment methodology to determine whether to extend the life of existing insulators in service.
- Understanding the impact of corona on the end fitting seal will help transmission line design strategies to improve the length of component life.

2012 Products

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<tr>
<td><strong>End Fitting Seal Evaluation:</strong> The E-field levels needed on an end fitting seal to cause corona damage have not been well investigated. In this task, small-scale testing will be performed to evaluate what E-field levels are needed to initiate water-drop corona on the end fitting seal. As part of this task, the end fitting seal for each manufacturer will be defined. This product will present the results of the small-scale tests and propose E-field limits for each of the end fitting seal designs tested.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>E-field Modeling Software: Corona Ring E-field:</strong> The EPRI software for E-field on Polymer Insulator Calculations (EPIC) will be upgraded to calculate the e-field on the surface of corona rings.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Polymer Insulator Population Assessment Software: Ver. 2:</strong> A new version of software will be developed that will include an analysis report feature and references to relevant polymer insulator inspection and assessment guides.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Short term tests for Polymer Insulators: Discharges in Rods:</strong> This product will document the development of a short-term aging test to assess the impact of discharge activity internal to a fiberglass rod on the life of an insulator.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Results from the 230 kV Aging Chamber:</strong> The 230 kV Accelerated Aging Chamber has been running for nearly 6 years, with more than 40 polymer components being aged. This product documents the aging test results throughout the test in a format that is easy to navigate.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
</tbody>
</table>
# Electric Power Research Institute 2012 Research Portfolio

**Update of Polymer Insulator Failures Through 2012:** EPRI regularly tracks polymer insulator failures across the industry to watch for potential batch problems, application problems, or other trends across the industry that might otherwise be overlooked by utilities with a much smaller dataset. This report summarizes the failures collected through 2012.

**Polymer Insulators Reference Book:** This reference book will be a compilation of existing EPRI reports and new research findings as a single source of information.

**Future Year Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td><strong>E-field Modeling Software: Refinement:</strong> The EPIC software for calculating electric fields on transmission line insulators will updated to increase usability and fix any bugs discovered in previous releases.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Polymer Insulator Population Assessment Software: Ver. 3:</strong> This product will include further improvements to the user interface, improve on the output reports based on user feedback, and address any bugs discovered. Lessons learned from population assessment research will also be implemented into the software.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Short term tests for Polymer Insulators:</strong> This product will evaluate the results of short-term aging of polymer insulators to determine how the tests and the results can be used to help utilities refine their procurement requirements.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Results from the 230 kV Aging Chamber:</strong> The 230 kV Accelerated Aging Chamber has been running for a number of years, with more than 40 polymer components being aged. This product documents the aging test results throughout the test in a format that is easy to navigate.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Polymer Insulator Vintage Guide Update:</strong> EPRI assesses information related to polymer insulator vintages to ensure that the information is up to date. This product will add information of insulator design changes made by manufacturers and include any new and relevant manufacturers as decided by the Insulators Task Force</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

**P35.012 Ceramic Insulator Integrity Assessment (060456)**

**Key Research Question**

Currently, millions of ceramic insulators are approaching or have exceeded the end of their intended service life. Since a large number of transmission lines were built in the 1950s and 1960s, these ceramic insulators are 50 years old. Although the performance of ceramic insulators has traditionally been very good, the number of problems observed is rising. Simultaneously, the number of ceramic insulators in service for more than 30 to 40 years has also increased significantly. Concerns are growing about performance issues with the current population of insulators and the availability of inspection techniques to identify high-risk units prior to failure.

Concerns have also been raised over the performance of new insulators acquired from manufacturing facilities that have not supplied utilities with insulators in the past. Lessons that traditional manufacturing plant personnel have learned over past decades of manufacturing may not have been transferred to the new plants. In addition, many utilities that have not traditionally used glass insulators are considering this technology. Glass and
porcelain insulators that are coated with silicone rubber in manufacturing are also being considered, and utilities lack experience with this technology.

**Approach**

This project will initially focus on suspension insulator bells, addressing the following areas:

- **Inspection and Assessment Tool:** This project investigates the development of field tools to assess the condition of insulator strings. In 2009, the technology was shown to be effective in identifying insulators with cracks outside the metal from a distance of 40 feet. The technology is being further developed to be remotely controlled with some automated features. In addition, the technique is being refined to identify cracks in the insulators located underneath the metal cap.

- **Insulator Identification:** When performing population assessments, it is important to know what manufacturer is installed and the year of manufacture. This project will develop a guide to identify insulators and describe their design characteristics so that informed decisions about population management can be made.

- **Evaluation of New Porcelain/Glass Discs Units:** This project assesses issues with porcelain/glass disc insulators procured from new manufacturing plants. In 2007 through 2009, M&E tests were performed and the results compared against standards and over 3000 M&E historical test results. In 2010, the testing expanded to include thermal mechanical cycling tests and includes samples of aged porcelain and glass insulators to provide a reference for comparison. In 2011 & 2012, increased thermal limits will be explored.

- **Electric Field Modeling:** This project will enhance the EPRI's Polymer Insulators E-field Modeling software, adding the ability to calculate the E-field around porcelain or glass insulators.

**Impact**

This project may have these impacts:

- Help members evaluate and identify high-risk ceramic insulator strings or populations of insulator strings prior to failure.
- Provide members with a greater choice of vendors and technologies, enabling lower cost or improved technical solutions.
- Assist members in addressing both existing and new insulation applied in contaminated environments.

**How to Apply Results**

- Operation and maintenance personnel can apply the new inspection technologies developed to evaluate in-service populations of porcelain insulators.
- Design and procurement personnel will use the information provided on the testing of new porcelain discs and glass insulators to make better-informed decisions when selecting and procuring insulators.
- The EPIC electric field modeling software will help users to understand the magnitude and impact of electric field grading designs on insulator strings.
- Knowing the make and model of insulators will help assess in-service populations.
### 2012 Products

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<tbody>
<tr>
<td><strong>Testing and Evaluation of New Porcelain/Glass Disc Insulators (Thermal – Mech. Increased temp. extremes):</strong> New standards are being developed with greater temperature extremes. By testing at these greater extremes, EPRI will gain understanding of insulator performance limits and quality of insulator manufacturing. The extreme temperature test will be useful to utilities operating in such environments.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Porcelain / Glass Insulator Vintage Guide:</strong> Knowing what type of insulator is installed is key to effective population assessments. This document will be a guide on how porcelain and glass insulator designs changed over the years and what distinguishes different manufacturers from each other. This guide will also help utilities identify the manufacturer and vintage of insulators installed on their system.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>E-field modeling:</strong> This software will calculate the voltage distribution along a string of porcelain or glass insulators. Utilities can use this information to improve grading of the insulators to reduce the effect of pin corrosion and corona.</td>
<td>12/31/12</td>
<td>Software</td>
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<tr>
<td><strong>Testing and Evaluation of New Porcelain/Glass Disc Insulators (Thermal – Mech. Increased temp. extremes):</strong> New standards are being developed that include increased thermal -mechanical temperature limits. New and aged insulators will be tested at increased thermal limits to determine insulator performance and impact on the M&amp;E testing. This product will document the findings of this work.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Failure Database:</strong> As the population of porcelain and glass insulators age, failures are likely to occur. This task will collect porcelain and glass failure information and document manufacturer trends, vintage, and installation environments.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Developing Vibration Tests to Q&amp;A New Units:</strong> Tests currently used to inspect porcelain insulators for internal cracking are destructive. This task will develop a new nondestructive method for evaluating porcelain insulator strings for internal cracks. This product will provide an update on the development and its effectiveness.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>E-field modeling software update:</strong> The EPIC software will be updated to include the results of laboratory tests, increase the insulator library selection, and fix any bugs found in previous versions.</td>
<td>12/31/12</td>
<td>Software</td>
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P35.013 Increased Power Flow Guidebook and Ratings for Overhead Lines (069259)

**Key Research Question**

The demand for electric power over transmission circuits is increasing faster than transmission assets can manage. This trend has pushed the capacity of many existing transmission circuits to their design limits. In addition, much of the grid has already aged beyond its original design specifications. These issues are affecting the grid with an increasing number of bottlenecks, and other congestion and reliability problems. The power
industry is realizing that the electric power infrastructure requires attention, and there is a need to identify methods and obtain tools for pushing more power through their existing assets. In addition, there have been recent mandated regulatory requirements on the establishment of transmission circuit ratings, and power companies need to have tools available to establish line ratings in a scientifically rigorous manner.

Approach
To meet the research needs of the power industry in this area, EPRI will continue to develop software tools and methodologies related to the design, engineering, system planning, and operation of overhead transmission lines (and other transmission circuit components), and investigate and document information on the state-of-the-science and best-practices on increasing and optimizing power flow through existing assets. Information on improvements in applications, thermal models, instrumentation, secure telemetry, and case studies will be identified, developed, and documented. Training and technology transfer activities and tools, such as tutorials, guides, workshops, and conferences, will continue to be developed in parallel with the research and development work.

This project focuses on overhead transmission lines, and is executed in coordination with corresponding projects for underground cables (Project P36.004) and substation equipment (P37.107). Feedback from EPRI member engineers, operators, designers, and planners will be sought during advisory meetings and workshops to identify future improvements.

Application of the R&D products that result from this project will aid electric power companies to more fully utilize their existing assets more economically, and with continued reliability, safety, and public acceptance.

Impact
The results from this project will provide the tools, information, training, and guidance needed by power companies to assess and implement increased and optimized power flow strategies for their specific needs, and with continued reliability, safety, and public acceptance. These results will help enable power companies to:

- Provide guidance for experienced technical staff, as well as reference and training materials for the next generation of power industry technical leaders
- Increase and optimize power flow through overhead lines and entire transmission circuits
- Defer capital expenditures and new construction
- Improve transmission circuit reliability and safety
- Optimize energy transactions through rating forecasts
- Ride out emergency situations safely and reliably
- Avoid unnecessary system outages

How to Apply Results
Transmission engineers, operators, planners, researchers, and IT personnel will use the computer programs and methodologies of this project to increase and optimize the ratings of their circuits. Software products can be applied for the benefits described above, and the methodologies on how best to apply all results can be obtained through EPRI guidebooks, reports, and training materials.

Members can use delivered reports as reference sources and guides for implementing increased power flow strategies, and for training their engineers in increased power flow technologies. Reports and references also compare the economic benefits of increased power flow technologies, enabling EPRI members to make informed decisions when choosing options for their specific applications.
### 2012 Products

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<tr>
<td><strong>Increased Power Flow Guidebook - 2012:</strong> The Increased Power Flow Guidebook (Platinum Book) will continue to be augmented with more and new material on the state-of-the-science and best practices for increasing and optimizing power flow through existing circuits. The needs for the guidebook are identified by industry experts and EPRI member advisory groups. An Increased Power Flow Wizard will be included with the Platinum Book.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Transmission Ratings Workstation (TRW) 1.0:</strong> The Transmission Ratings Workstation (TRW) will be initiated in 2012. This will incorporate EPRI's Dynamic Thermal Circuit Rating software (DTCR) and other ratings-related software modules under one roof. The product will be designed for performing rating studies, evaluating and optimizing static ratings, real-time ratings, and forecasted ratings for overhead lines and entire transmission circuits.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Evaluation of Instruments for Line Ratings: Laboratory and Field Studies:</strong> Over the past several years, there have been many developments in the area of field instruments for monitoring the thermal state of overhead lines for rating purposes. These instruments monitor various parameters, such as conductor sag, temperature, tension, local weather conditions, etc. Several new instruments have recently come to market, and others are being developed and/or improved. EPRI has been at the forefront of assessing these technologies, and has used a wide range of these instruments in several projects. In 2012, EPRI will document the experiences with instruments from these projects, and will perform some basic laboratory assessments of potentially useful instruments. The results will be delivered in this Technical Update.</td>
<td>12/31/12</td>
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### Future Year Products

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<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Verification of Overhead Line Ratings using LiDAR Technologies:</strong> The use of LiDAR technologies is gaining a foothold in the industry for use in defining overhead line ratings, and LiDAR technologies are being improved at an increasing pace. This Technical Update will provide an overview of the subject, and provide guidelines for the application of the technology.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Proceedings of the Increased Power Flow Workshop:</strong> An IPF Workshop, covering all aspects of increasing power flow, will be held in 2013. Proceedings of the workshop will be published.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Transmission Ratings Workstation (TRW) 2.0:</strong> The Transmission Ratings Workstation (TRW) will continue to be developed in 2013. This program will incorporate EPRI's Dynamic Thermal Circuit Rating software (DTCR) and other ratings-related software modules under one roof. The product will be designed for performing rating studies, real-time ratings, and forecasted ratings for overhead lines and entire transmission circuits.</td>
<td>12/31/13</td>
<td>Software</td>
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</table>
P35.014 High Temperature Operation of Overhead Lines (069260)

Key Research Question

Electric power companies can increase the power transfer capacity of transmission lines by raising the conductor operating temperature. The effects of high operating conductor temperature are reduction in conductor ground clearance, loss of conductor strength, and damage to connectors and other overhead line components. In addition to the mechanical performance, transmission line owners, operators, and designers must also be aware of the effects of high temperatures on the existing corona and thermal models. These models were based on conductor temperatures much lower than those encountered by an overhead line today. Inaccurate models may produce results that could exceed the limits imposed by state or federal regulatory agencies.

Research is needed to investigate premature failures of conductor and conductor accessories from thermal cycling due to high-temperature operations. Conductor accessories include conductor splices and dead-ends, dampers, spacer dampers, and all hardware attached to the conductor of an overhead line. Research is also needed to investigate high-temperature effects on corona, thermal, and other models used to evaluate electrical effects, heat-transfer capability, and other performance indicators of an overhead line.

With accurate data, electric power companies are able to assess the risks of high-temperature operations. They can then establish a temperature limit below which overhead lines can operate reliably. This limit can further be raised by developing appropriate mitigation measures.

Approach

This project evaluates the impact of high-temperatures on the mechanical, electrical, and thermal performance of overhead lines. Solutions are developed and models enhanced to allow power companies to raise transmission line capacities safely, reliably, and with confidence.

Every component of an overhead line will be studied. The project started with the investigation of the most vulnerable component. Because fittings at the connection point are the weakest links in a transmission system, the project first focuses on establishing temperature and duration limits for these fittings beyond which they may encounter thermal or mechanical failure. It then investigates and tests different mitigation methods to alleviate the thermal impact. The project also assesses the accuracy of existing thermal and corona models at elevated operating temperatures. Research results will be used to update these models. All other knowledge gaps for high-temperature operations will be identified. Research and tests will be performed to address these gaps.

A report is prepared every year, summarizing all research results conducted by both EPRI and other organizations on the performance of conductors and conductor accessories operating beyond the conductor annealing temperature of 93°C. The information is updated each year. To facilitate the users in selecting the right temperature for an overhead line, a high-temperature matrix software is also developed. The matrix identifies readily the line components that may fail when an overhead line is operated at a given temperature. Detailed information can be accessed by drilling down into the matrix. In addition, calculators for conductor annealing, current capacity at various temperatures, and methodologies to evaluate component life, when available, are included in the matrix. The project provides a holistic approach to high-temperature operations.

Impact

This project may have the following impacts:

- Raise confidence in operating overhead lines at high temperatures to increase transmission capacities
- Avoid damage to overhead line components and subsequent line failures
- Adopt mitigation measures to achieve additional transmission power
- Provide accurate prediction of electrical and thermal performance of overhead lines
How to Apply Results

Transmission engineers can use information from the project to evaluate the risks of raising a conductor to a given temperature. Mitigation methods developed in the project can be adopted to increase the operating temperature of an overhead line. By using this information and the methods, transmission engineers can more accurately evaluate the electrical and thermal performance of overhead lines. Members can then establish internal guidelines for high-temperature operation of their overhead lines.

2012 Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Guide for High-Temperature Operation - Progress Report: The guide provides an holistic approach for high-temperature operations. The guide is updated annually based on new results from internal and external research. Results from testing of mitigation measures for high temperature operations and from the development of a model for life-prediction of two-new connectors may be included. The section on fundamentals of high-temperature operations will be expanded.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>HTC (High-Temperature Conductor) Matrix: Version 4.1: The HTC Conductor Knowledgeable Matrix applet will be updated with new information, data, and research results from the previous year's high-temperature operation guide. Preliminary data from testing of mitigation measures will be added to the applet. User interface will be improved based on input from members. A calculator to cover high-temperature corona and thermal models may be included.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td>Performance of Compression Fittings at High Temperatures: A report providing an update on the performance of various types of compression connectors at high temperatures based on the most recent test data from EPRI research will be published. The report will include description of the test setup, test protocol, observations, conclusions and recommendations.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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Future Year Products

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<tr>
<td>Guide for Operating Overhead Lines at High-Progress Report: The guide provides an holistic approach for high-temperature operations. The guide is updated annually based on new information from internal and external research. Preliminary test data on the impact high temperature on conductor hardware and accessories will be reported. The section on fundamentals of high-temperature operations will continue to be expanded.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>HTC (High-Temperature Conductor) Matrix: Version 5.0: The HTC Conductor Knowledgeable Matrix applet will be updated with new information, data, and research results from the previous year's high-temperature operation guide. Final data from testing of mitigation measures will be added to the applet. User interface will be improved based on input from members. A calculator to predict the life expectancy of two-stage connectors may be added.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td>Measures to Mitigate High-Temperature Effects on Connectors: This update will detail the work done in determining the effect of mitigation devices on the performance of connectors operated at temperatures above their rated temperature levels.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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</tbody>
</table>
Guide for Operating Overhead Lines at High-Progress Report: The guide provides an holistic approach for high-temperature operations. The guide is updated annually based on new information from internal and external research. Final test data on the impact high temperature on conductor hardware and accessories will be reported. The section on fundamentals of high-temperature operations will continue to be expanded.

12/31/14  Technical Update

HTC (High-Temperature Conductor) Matrix: Version 5.1: The HTC Conductor Knowledgeable Matrix applet will be updated with new information, data, and research results from the previous year. Preliminary test data on the impact high temperature on conductor hardware and accessories will be included. Information on the basics of high-temperature operation will continue to be expanded. The software will be reviewed for minor improvements. A new calculator to facilitate high-temperature operations may be added.

12/31/14  Software

Increased Transmission Capacity Workshop Proceedings: The proceedings of the Increased Transmission Capacity Workshop will be compiled into a technical update. Various new technologies and applications of technologies as well as utility use cases may be presented at the workshop.

12/31/14  Technical Update

P35.015 Performance and Maintenance of High-Temperature Conductors (065550)

Key Research Question

Recently developed high-temperature conductors offer the advantages of higher current capacity, lower conductor sag, and lower line losses than conventional ACSR (aluminum conductor steel-reinforced) conductors. These conductors are also known as advanced conductors, high-temperature low-sag conductors, or simply HTLS conductors. Short-term experience of these conductors was gained through an EPRI field demonstration project that was completed in 2009. Knowledge of the long-term performance of these high-temperature conductors, especially those with a carbon fiber composite core, is lacking. A number of issues have to be addressed to assist the power industry to apply this new technology properly. Furthermore, existing tools and procedures for conventional conductors have to be evaluated for applying live-line maintenance to these high-temperature conductors.

Approach

This project addresses critical issues related to the long-term performance of high-temperature conductors. The most immediate needs are for carbon fiber core conductors, which are the least known and the most novel of all high-temperature conductors. The core of this type of conductor consists of carbon and glass fibers that are more sensitive to heat and other environmental conditions than steel used for conventional ACSR (aluminum conductor steel-reinforced) conductors.

A test protocol to qualify this type of conductor was developed and applied to a carbon fiber core conductor in 2009. In 2010, the performance of two different carbon fiber core conductors was evaluated using the same protocol. In 2011, the same protocol is to be applied to a third carbon fiber core conductor. Concurrently, an accelerated aging test is to be carried out on a range of commercially available high-temperature conductors for evaluating the long-term performance of these conductors, their splices, and dead ends. Results of the accelerated aging test, which takes a year to complete, will be compared with that of the much shorter qualifying test. Reference will be made to the experience gained on non-ceramic insulators that apply similar technology for their core to develop additional tests to evaluate these high-temperature conductors with the goal of providing a purchase specification for carbon fiber composite core conductors to the users.
Starting in 2012, preparation of a comprehensive guide for the selection and application of various types of high-temperature conductors will be initiated. The guide will include the most current information from manufacturers, experience gained from users, results obtained from research, purchase specifications for procurement as well as maintenance tools and procedures for high-temperature conductors. The guide will be updated annually as new research results and data become available.

Impact

The project may have the following impacts:

- Provide information and tools that are currently not available to evaluate the performance of various high-temperature conductors.
- Provide maintenance procedures and recommend tools to ensure the safety of utility personnel and the reliability of transmission lines.

How to Apply Results

The test protocol developed under this project provides design engineers with a tool to qualify and compare different carbon fiber composite core conductors. The accelerated aging test provides useful information on the long-term performance of these high-temperature conductors. All research results provide members with information for comparing and selecting proper high-temperature conductors for their applications. Developed maintenance procedures and recommended tools for advanced conductors can be incorporated into members' maintenance manuals.

2012 Products

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<tr>
<td>Maintenance Issues of High-Temperature Conductors: Research Results: Test results from the current year will be documented in a report. The report will also provide an update on live-line maintenance procedures for high-temperature conductors, including details on the method and tool for the application.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Accelerated Aging Test of High-Temperature Conductors and Connectors: Results from thermal cycling of high-temperature conductor-connector systems provide valuable information for determining the expected life of these conductors. A model based on thermal-cycling results and studies of connector materials and designs will be developed to provide engineers with a valuable tool to determine the life expectancy of these conductors.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Guide for Selection of Application of High-Temperature Conductors - An Outline: An outline of the guide will be developed. Topics to be included in the guide will be identified. A brief description of what will be covered under each topic will be provided.</td>
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<tr>
<td>Guide for Maintenance of High-Temperature Conductors: Test results and reports from previous years will be used to develop a guide on the maintenance of high-temperature conductors. The guide will also provide an update on live-line maintenance procedures for high-temperature conductors, including details on the method and tool for the application.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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</tbody>
</table>
### Guide for Selection and Application of High-Temperature Conductors

A guide will be developed based on the outline developed in 2012. Topics to be expanded for the year will be identified. Detailed information will be prepared for these topics. **Planned Completion Date:** 12/31/13

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</table>

### Guide for Maintenance of High-Temperature Conductors

The guide developed in the previous year will be updated to include the latest findings of research conducted. The guide may also be expanded to include further high-temperature conductor maintenance issues relevant to member utilities. **Planned Completion Date:** 12/31/14

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</table>

### Guide for Selection and Application of High-Temperature Conductors

The guide developed in 2013 will be updated and expanded in 2014. Topics to be expanded for the year will be identified. Detailed information will be prepared for these topics. **Planned Completion Date:** 12/31/14

<table>
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### P35.016 New and Emerging Inspection and Sensing Technologies (070600)

#### Key Research Question

As assets age beyond their design margin, the ability to inspect and assess their condition has become vital. New and emerging inspection and sensing technologies are essential to meet this need. Many utilities are unaware of new technologies, and in many cases unsure of their performance due to lack of field experience. As new issues emerge, new technologies must be identified and possible solutions investigated.

#### Approach

The project will take a three-pronged approach to addressing the research needs:

- Identify and document new and emerging inspection/sensing technologies to increase members' awareness.
- Document use cases where new and emerging technologies have been utilized in the field.
- Identify gaps in currently available inspection technologies and possible applicable technologies to meet members' requirements.

In 2011, a database with applicable technologies was developed, where members were able to look up the component to be inspected (e.g., insulators, sub-grade components, or others) and determine applicable sensing and inspection technologies. The database also included use cases documenting utility experiences with specific technologies. A report detailing new and emerging technologies was also delivered. Building on that foundation, project activities in 2012 will include:

- Updating the inspection/sensing technologies database based on member input and new information
- Add use cases to the database
- Document gaps or needs, and develop a vision for future inspection and sensing technologies
- Laboratory and field evaluation of new and emerging technologies

In future years, if experience with new inspection/sensor technologies is not available, round-robin-style testing will be performed in controlled and field environments to provide members with knowledge and performance information on inspection/sensing technologies that they have not applied to date.

#### Impact

By being aware of the latest technologies and having easy access to other utilities' experience as well as performance testing, members will be able identify appropriate technologies more easily and have more confidence in their application.
By identifying gaps and possible technologies, future research and development needs can be addressed.

**How to Apply Results**

When faced with an issue concerning a specific component, members would utilize the database to become aware and informed of all applicable inspection/sensing technologies. In addition, they would have easy access to other members’ experiences in addition to third-party performance results.

### 2012 Products

<table>
<thead>
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<tr>
<td><strong>Evaluation of Emerging Technologies:</strong> New and emerging inspection and sensing technologies will be evaluated in laboratory and field testing. This product will document the performance and provide users with a basis for their application. Members will be invited to attend a demonstration of the technologies being evaluated.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Inspection &amp; Sensing Technology Database (including use cases):</strong> This is an update to the database initiated in 2011. This product will contain new inspection and sensing information and will include additional utility use cases.</td>
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<td>Software</td>
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### Future Year Products

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<td><strong>Update Inspection &amp; Sensing Technology Database (including use cases):</strong> This is an update to the database initiated in 2012. This product will contain new inspection and sensing information and will include additional utility use cases.</td>
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### P35.017 Design and Construction - Approach and Practices (072004)

**Key Research Question**

The power industry wants to construct reliable and cost-effective overhead lines. A reliable and cost effective line requires not only a line that performs well but also a line that be constructed easily and safely. Well-coordinated designs for ease of construction are required. It is therefore crucial that close coordination is maintained and information is shared between design and construction staff. In the Overhead Transmission program, research is being conducted on line components, maintenance procedures, methods, and work practices for overhead lines in separate areas and often involves separate members. The research has produced products that may be useful but often overlooked by one another.

This research will develop a comprehensive, single source guide for the coordination of design and construction practices. Overhead line designs may be optimized to allow good construction practices while construction practices will be developed for new designs that requires unique or new approaches.
Approach

The project will focus on issues that have major impact between design and construction and that are critical to the cost and safely of the overall line. The project will review research products developed in other projects within the Overhead Transmission program, evaluate their suitability, and adapt them for use in the design and construction of overhead lines. Information includes technical data as well as experiences gained from constructing, operating, and maintaining overhead lines. Tools include software, equations, and methodologies. The information will be assembled in a form that is easily available to overhead line designers and construction engineers. The project will cover materials, designs, construction, practices, and approaches and will include various line components. The most current information beyond that being used by overhead line designers and construction engineers will be developed and possible gaps identified.

Impact

The project may have the following impacts:

- Enable overhead line designers to select proper designs and line components
- Enable overhead line construction staff to build lines safely and easily
- Develop construction practices for unique and new designs
- Reduce construction, operation, and maintenance costs

How to Apply Results

Overhead line designers can apply guidelines developed under this project in selecting proper and cost effective designs, materials, components that can be constructed easily and safely. Overhead line constructors can apply approaches and practices developed under this project to build lines safely and cost-effectively.

2012 Products

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</thead>
<tbody>
<tr>
<td><strong>Guide for Evaluation of Overhead Line Components</strong>: Research data on different overhead line components from the Overhead Transmission program are to be assembled and reviewed for suitability of its use for the Transmission Line Design Practice and Approach. One or more components will be reviewed each year, and a document will be prepared to assist designers in evaluating the technical merits of line components. A guide addressing all the components and including design approach and construction practice will be prepared in a future year.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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| **Design and Construction - Approach and Practices**: Research data on maintenance and construction practices influenced by designs are to be assembled. The impacts on the practices by different designs are to be reviewed. Construction approach will be evaluated and practices will be developed. | 12/31/12 | Technical Update |

Future Year Products

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<td><strong>Guide for Selection of Overhead Line Components:</strong> Research data on different overhead line components from the Overhead Transmission program are to be assembled and reviewed for suitability of its use for the Transmission Line Design Practice and Approach. One or more components will be reviewed each year, and a document will be prepared to assist the designers in selecting a proper component for the application. The selection will include both technical and economic evaluations.</td>
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<td><strong>Guide for Evaluation and Selection of Overhead Line Components:</strong> A guide for evaluation and selection of overhead line components may be developed based on the work done in preceding years. The guide may include technical and economic information to assist users in evaluating the overall costs of line components for the selection of a proper product for their application.</td>
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Unmanned Air Vehicles for Transmission Lines (072005)

Background, Objectives, and New Learnings

There is a potential that unmanned air vehicles (UAVs) could be a valuable asset to utilities to help in their inspection of transmission lines. This project will evaluate UAVs and remote sensing technologies for inspection and condition assessment of overhead transmission lines. Researchers will first identify functional requirements for UAV inspection and perform a market survey to identify available UAV inspection technologies, inspection services, and their costs. Based on the findings, the project team will then conduct laboratory and field demonstrations of promising UAV inspection technologies.

Results of the project will help utilities understand additional options for inspecting transmission lines and may also help identify future research, development, and demonstration needs.

Although requirements for transmission reliability and availability have increased, utilities are also seeking to reduce costs while squeezing more performance from existing—and often aging—assets. Advanced technologies such as UAVs may enable utilities to maintain or increase transmission reliability with smaller budgets and fewer personnel.

EPRI evaluated UAVs for transmission inspection in the late 1990s. Tests demonstrated that the concept of using fixed- and rotary-wing UAVs for line inspections was sound; however, the low-cost sensor packages used in the tests could not accurately determine the position of individual structures, or identify a significant number of conditions and defects. With the advances in sensor technologies, and additional development and experience in military applications, UAV technology has matured and is ready for reevaluation as a transmission inspection tool.

Project Approach and Summary

The project team will first identify applications and functional requirements for UAV inspection of transmission lines and will create a vendor and technology inventory to identify vendors and technologies that can meet the functional requirements for rotary- and fixed-wing UAVs. This inventory may include sensor, navigation, and communications technologies, UAV inspection service providers, and costs. With this information, the project team will perform a gap analysis to identify and understand the issues and barriers that must be addressed before developing functional specifications for UAV transmission inspection systems.

Benefits

Transmission line inspections are essential to pinpoint stressed or at-risk components prior to failure, preventing outages and optimizing maintenance efforts.

Traditional transmission line inspection methods are costly and labor-intensive. Utilities use manned aircraft for fast and slow fly-by patrols, and also conduct walking or driving line patrols, as well as climbing or bucket truck inspections. UAVs offer the potential to improve transmission line inspection by reducing labor costs, improving safety of personnel and equipment, increasing operational flexibility, and providing expanded inspection capabilities.

Today's UAVs can carry an array of remote sensing equipment including high-resolution digital still and video cameras, infrared cameras, and light detection and ranging (lidar) systems. These sensors, coupled with GPS navigation and data communications systems, may enable UAVs to augment or replace traditional methods for performing a variety of inspections.

Fixed-wing UAVs could potentially perform flyby patrols for assessment of transmission structures and components at lower costs than manned aircraft. Portable rotary-wing UAVs could be deployed to hover near a tower to provide a high-definition, birds-eye view to enable field inspectors to assess the condition of insulators, conductors, and other components of interest. After severe storms or during flooding, when ground response is limited, UAVs could be used to assess damage and provide the information to the emergency response planners.
115/138kV Accelerated Aging Test to Evaluate Polymer Insulators Installed with and without Corona Rings (069303)

Background, Objectives, and New Learnings

Since 2006, utilities have experienced mechanical failures of polymer insulators on 115 kV and 138 kV transmission lines. Many inspections by utilities have revealed significant levels of discharge activity on their 115 kV and 138 kV polymer insulators, which is a key element in mechanical failures. Examination by EPRI revealed that corona activity is responsible for accelerated aging and in some cases significant degradation of the rubber and the end fitting seal. The correct application of corona rings can mitigate the high electric fields (E-fields) that cause corona activity, reducing the risk of failure.

For many years, it has been recommended that corona (grading) rings are not necessary for voltages at or below 161 kV. Although some manufacturers are now recommending the standard application of corona rings on polymer insulators for voltages of 115 and 161 kV, the in-service population of polymer insulators installed without corona rings needs to be addressed. Utilities need to understand the options to deal with the significant population of polymer insulators that may be at risk of failure.

EPRI has been investigating these failures and their mechanisms and has provided detailed recommendations on how to address the issue when specifying new units and inspecting in-service units for problems. These recommendations can be found in EPRI report 1015917, “Application of Corona Rings on 115/138 kV Polymer Transmission Line Insulators”.

There are still a number of open questions regarding this subject:

- What is the expected loss of life of units that have been in-service without corona rings
- What is the difference between the different insulator designs
- At what point is retrofitting a corona ring more cost effective than insulator replacement

Continuous dry discharge activity is harmful to the rubber weathershed and end fitting seals of polymer insulators. The prolonged exposure to discharge activity rapidly ages the rubber in as little as six to seven years, leading to cracking and eventually exposure of the rod to the environment. This damage, in turn, may result in failure of the polymer insulator, either electrical or mechanical. Preventing discharge activity reduces the risk of polymer insulator failure. Prior research has shown that this prevention can be achieved by applying corona rings at the lower voltages.

EPRI has been running accelerated aging tests on polymer insulators for the past 15 years. Utilities have used the results of the tests to improve installation practices, improve their purchasing specifications, improve their inspection techniques, as well as to make effective population assessment decisions.

Project Approach and Summary

Approach

This project will investigate these questions by conducting multiyear, multistress accelerated aging on full-scale insulators. The current plan is to place 30 or more suspension, dead end, and braced post units from five different insulator designs under electrical and mechanical stress equivalent to that found in service. New units will be aged with and without corona rings. Service-aged units provided by participating utilities will be included in the test to show the effect of retrofitting a corona ring onto the insulator and the impact of not installing a ring. The electrical stress (the E-field magnitude) of the participating utility configurations, as well as the aging test, will be calculated by 3-D modeling. The modeling is vital to the test design, but it also provides useful information to the participants on their configuration’s performance. EPRI’s EPIC and other E-field modeling software will be utilized.
Project Summary
This project will consist of 30 polymer insulators from five manufacturers. The test frames will be located outdoors in Lenox, MA. An artificial rain system will be installed to enhance wet discharge activity and accelerate aging. The insulators will also be exposed to all four seasons. The insulators will be inspected visually and for loss of hydrophobicity semi-annually. An IR/UV inspection will occur annually. A detailed set of evaluation tests will be performed at the end of the test.

Benefits
This project strives to develop decision support information necessary for utilities to manage populations of 115/138 kV units installed without corona rings. Utilities may be able to create and time a replacement program for insulators in service, prioritized by design and expected remaining life. Utilities will also be able to make informed decisions on proper application of corona rings when developing standards for new installations. Addressing the application of corona rings for both serviceaged and newly installed insulators may increase their service life and increase the reliability of utilities’ systems.
Inspection And Assessment for Lattice Structures using Guided Waves and Electrochemistry (070972)

Background, Objectives, and New Learnings

A huge gap has been identified in the inspection and assessment of lattice transmission structures. Traditional techniques have been limited to direct assessment and soil diagnostics, and each of these technologies has limitations in cost and accuracy. EPRI has created a supplemental project that is designed to test a new application of an existing technology against a newly developed technology. Linear Polarization Resistance is an electrochemical technique that quickly measures corrosion rates. Electro-Magnetic Acoustic Transducer (EMAT) is an acoustic technique that has been tested with various levels of success on steel poles and anchor rods. The concept is to utilize both methods and then confirm the results through excavation in a series of field trials in the participant’s service areas.

The purpose of this project is to identify the accuracies, costs, and risk of new and emerging inspection technologies.

Project Approach and Summary

The first activity through a participant’s service area will be assessing the structures using EMAT and a new EPRI portable terminal station, followed by an excavation and a direct visual assessment down to four feet below grade. This dual inspection is necessary to understand the effectiveness of the assessment technique under test. Once a suspect structure has been identified as having significant degradation, a full excavation will be made to confirm the assessment. This excavation will be completed on 2% of all structures inspected.

Benefits

A supplemental project in 2009 was completed for inspection and assessment of galvanized steel poles. This project is similar in concept as it is designed to be a round robin evaluation of two emerging technologies for a structure type that is mature and in need of an inspection method.

Lattice structure inspections below grade can be costly due to loading issues and the associated stabilization required during excavation. Few of these structures can be excavated to the bottom of the grillage unless they are a tangent structure without transverse loads. This practice can also lead to a backlog of open structures that have not been repaired and have been disturbed.

The public may benefit from keeping the rates affordable even with the higher need to inspect the aging transmission infrastructure and maintain it at lower cost.
Daylight (UV Imaging) Discharge Inspection Interest Group (064856)

Background, Objectives, and New Learnings

The technology for viewing corona and arcing discharges in full daylight has been around for a number of years. Many utilities now possess this technology and are using it for operation and maintenance of power lines. One of the difficulties in fully applying this technology is the interpretation of the data or visual images. This is because arcing is often interpreted as corona and vice versa, and the location of the discharges and their effect are sometimes misdiagnosed. This failure may lead either to unnecessary intervention or to equipment failure.

The Daytime Discharge Inspection Interest Group was initiated in 2007 to help the industry maximize the use of Daylight UV camera technology for inspection and maintenance of the power network. An ongoing challenge is the improved understanding and diagnosis of the visual images taken from the camera.

The objectives of this project are to move this technology forward by:

- Developing training material and updating existing material with new research findings
- Undertaking fundamental research on UV & IR inspection of transmission line components
- Providing a hands-on workshop and training

Project Approach and Summary

The focus of this project is the establishment of a Daytime Discharge Inspection Interest Group. DDIIG will act as the forum by which utilities can maximize the benefit of using this technology. In essence, the DDIIG will allow participants to share information, including vendor and utility experience, and have access to field guides, training, and a bulletin board for queries and advice. It will also provide the framework for setting inspector requirements.

This project also caters for those wishing to limit their participation to User Group meetings. This allows participants to share utility experience, keep abreast of vendor technologies, and facilitate user needs.

The Interest Group will be non-vendor-specific, encompassing all of the optical daytime corona inspection technologies currently available. The Interest Group’s mission will be to provide unbiased, technically sound, and current information.

Benefits

- Improve decision making when using this technology
- Receive training
- Share utility experiences
- Ensure consistent inspection standards

These benefits can ultimately translate into O&M cost savings.
Comparative Assessment of DTCR Technologies (072006)

Background, Objectives, and New Learnings

The demand for electric power over transmission circuits is increasing at a faster rate than the construction of new transmission facilities. This trend is pushing the capacity of transmission circuits to their design limits. The power capacity (i.e., the rating) of most overhead transmission lines is prescribed by the so-called “static rating” based on both the conductor configurations and the environmental conditions. Typically, very conservative worst-case assumptions about environmental conditions were used when developing these “static ratings”. Due to this conservative approach, significant extra power capacity exists beyond the design margin on most lines most of the time.

As part of its ongoing research in this area, EPRI has developed monitors, rating calculation methodologies, the Dynamic Thermal Circuit Rating (DTCR) software, workshops, and other products. Prior to undertaking capital intensive activities—such as building new lines, reconductoring, raising structure heights, replacing transformers, and putting lines underground—utilities can use this technology to maximize power throughput of existing assets, defer capital expenditures, and simultaneously increase safe and reliable operation of their assets.

Several types and classes of field instruments can be used to monitor the thermal state of overhead conductors for performing real-time ratings or for performing off-line rating studies. Some of these instruments are commercialized, and some are still in development. Power companies considering real-time or off-line ratings often have the question as to what instruments are best for them technically and economically. The answer is not always known, and the answer may depend on the details of the specific application.

In this project, EPRI will perform side-by-side comparisons of several instruments of different types, and document the results to help utilities understand and apply these technologies. A host utility will be needed for the field tests, or the project can be performed in a full-scale laboratory environment.

Project Approach and Summary

Tests and evaluations of instruments that may be used to monitor the physical state of overhead conductors for rating purposes will be performed in the field. A host utility will be needed for the field tests, or the project can be performed in a full-scale laboratory environment.

Benefits

The results of this project will help utilities apply rating technologies for the purpose of increasing or optimizing the power throughput of existing assets while maintaining reliability, power quality, and safety.
Full-Scale Verification of ArcFlash Thermal Energy Model at Transmission Voltages (072145)

Background, Objectives, and New Learnings

Arc flashes are a serious hazard that may potentially put people in life-threatening situations and cause great damage to existing assets. National Electrical Safety Code (NESC) and Occupational Safety and Health Administration (OSHA) safety rules have introduced requirements for electric utilities to perform arc flash hazard analysis of all electric facilities operating at and above 1000 volts. Most methods available at this time for analyzing the arc flash incident thermal energy were developed for low- and medium-voltage industrial and commercial settings. Previous extensive EPRI testing and analysis concluded that the currently available methods for calculation of incident thermal energies are not applicable to practical transmission situations and lead to inaccurate estimates of incident thermal energy. Hence, an improved computations method is needed to meet NESC and OSHA rules.

A new empirical arc model was developed, and more realistic curves were developed of incident thermal energy versus arc energy (current and duration), arc gap length, and distance from the arc gap axis (working distance) based on long gap tests (arc gaps up to 5 ft long). The research performed is expected to enhance the safety of live work on overhead lines and in substations. Summaries of EPRI’s research, general conclusions, and a new calculation equation are contained in EPRI reports 1022632 and 1022633.

Project Approach and Summary

In this next stage in this research, the arc model developed under laboratory conditions will be adapted to realistic live work transmission and substations situations through full-scale testing. This project will perform high-current tests, using instrumented mannequins on realistically mocked-up transmission structures and substation equipment. The developed equations will be verified and adjusted, if necessary, for these conditions. Conclusions and findings will be shared with the utility industry through improved computation equations, reports, and workshops.

This project meets EPRI’s mandate of conducting original research for the benefit of the public and its members. The project’s results are expected to answer how arc flashes affect personnel and may lead to improved safety of personnel. It fills the knowledge gap in modeling long arcs in practical situations on overhead lines and in substations.

Benefits

Participants will have access to the most recent information on arc flash issues as they relate to work on transmission lines and in substations, and to the necessary science and tools to develop the basis for compliance with NESC and OSHA safety rules. Tests planned as part of this project can also be witnessed.

This project is expected to improve the understanding of the impact of arcing on personnel in various work situations. Application of the results of this research may also allow live work in cases where this was previously not permissible or practical based on currently available computation methods. This capability may allow the utilities to perform necessary inspections and maintenance operations live, thus increasing the overall reliability and availability of the transmission grid.

EPRI computational methods and comprehensive reports on arc flash issues could benefit utilities that are developing their own processes and procedures to comply with NESC and OSHA standards that can ultimately lead to safer environments for workers and the public.
Evaluation of Emerging Line Surveying Technologies (071879)

Background, Objectives, and New Learnings

Many utilities are performing detailed surveys of transmission lines to address the regulatory alert issued by the North American Electric Reliability Corporation (NERC). This alert requires all transmission operators to assess by 2014 the precise physical characteristics of their high-voltage transmission lines relative to design specifications.

Some utilities are considering using LiDAR (Light Detection And Ranging) surveys, together with engineering software, such as PLS-CADD, to determine whether conductors comply with the NERC requirements. The surveys determine whether transmission lines have the required clearances under full rating conditions and specified environmental conditions.

An important factor utilized by the engineering software when processing the LiDAR data is the conductor temperature at the time of the survey. A number of approaches are used to determine this—for example, positioning weather stations along the transmission line and calculating the conductor temperature at the time of the survey. Uncertainty remains as to the applicability of this approach.

Alternate approaches are being proposed including measuring conductor temperature directly using a RF Sensor; utilizing infrared sensors from the LiDAR helicopter, or measuring wind speed in the helicopter directly and calculating the conductor temperature from knowledge of the load, wind velocity, ambient temperature, and solar intensity.

This project will identify and document technologies, perform testing to determine their applicability.

Project Approach and Summary

Identification and Documentation of Available Solutions
Emerging technologies and approaches will be identified and documented. Their fundamental concepts will be documented together with the published accuracy. Any fundamental limitations will be identified.

Full Scale Test Development
A full-scale transmission line at the EPRI Lenox Laboratory will be enhanced to control conductor temperature and sag. Conductors of various emissivity and diameters will be instrumented for direct conductor temperature measurement and sag and local environmental conditions.

Full Scale Testing
A scientific approach and test plan will be developed and agreed upon by the participants to perform. Blind testing of the technologies will be performed. The test condition will be unknown to the surveyors.

Field Assessment
EPRI has a number of utility test sites with spans instrumented to continuously measure conductor temperature, sag, and environmental parameters. These spans will be surveyed with the technologies and results compared against the direct measurements.

Participation in the development of test setups and approach plans will be encouraged.

Analysis of Data and Reporting
The survey data will be compared against the direct measurements documenting the performances.

Benefits
Through this project, participants can bring the knowledge they gain in developing new line surveying techniques that could benefit the industry, leading to greater safety.
Developing the capability to verify that the as-built line performance matches the line design specifications can help utilities to operate the line safely, meeting the intended safety and performance characteristics and increasing reliability.
Underground Transmission - Program 36

Program Overview

Program Description

Underground transmission (UT) faces a number of challenges. Utilities need better understanding of the condition of an aging UT infrastructure, which in many cases has exceeded its 40-year life expectancy, to strengthen existing cable systems and help asset managers make difficult upgrade and replacement decisions. Increased system robustness, higher capacity, and longer life will require development and use of newer polymer insulations at extra-high-voltage (EHV) levels with integrated sensors. An ability to exploit the dynamic overload capacity of buried power cables promises better asset utilization at marginal extra cost.

Transmission systems must deliver high power quality for the digital society, ideally immune from weather extremes and in many cases serving urban centers with limited space for infrastructure expansion. To meet these needs, the industry must accommodate increased use of buried power cables with greater power throughput, which places great importance on orderly replacement of mature cables with care that new advanced systems are at least as reliable. Transmission owners need guidance on the safe and more efficient use of new materials, equipment, and construction methods for UT systems to boost economic productivity and prosperity. Also needed are advanced design tools to increase the effectiveness of engineering resources, as well as to aid technology transfer to new knowledge workers. Efficient use of component materials with lower losses, less construction impact, easier replacement, and high recycle value would benefit the environment and increase sustainability for generations.

EPRI’s Underground Transmission program is made up of five research projects: Design, Construction and Operation of UT Systems, Extruded Dielectric Cable Systems, Laminar Dielectric Cable Systems, Cable Dynamic Rating and Increased Power Flow Guidebook and Develop and Deploy Superconducting Technologies. This research leads the industry in exploring and deploying promising new technologies and tools to help UT owners design and operate cost-effective cable systems with increased power capacity and longer lives, diagnose problems before outages occur, and repair them at minimum cost and within acceptable time periods.

Research Value

With the knowledge acquired through this research program, members will have access to information and products that can help them:

- Increase engineering staff efficiency and expertise
- Improve efficiency and quality in UT system design
- Lower installation and operating costs
- Improve transmission system reliability and safety
- Gain more accurate and timely knowledge about asset condition and life expectancy
- Develop tools and methods to design and operate the system with increased power flow
- Acquire strategic intelligence on emerging technologies
- Participate in new technology designs, testing standards, and equipment demonstrations

Approach

EPRI research in underground transmission will yield a variety of data and knowledge that will benefit members of the program. This information will be provided in a number of forms, and is expected to include the following:

- Software programs
- Reference books
- Manual of advanced and low-cost designs and construction/installation techniques
• Improved safety procedures, technologies, and tools
• Experimental verification of design models
• Development and demonstration of a number of monitoring assets
• User conferences, stakeholder meetings, and coordination with institutional funders
• Training workshops

Accomplishments
This program has delivered value to members in a number of ways. Recent examples include:

• Commercial release of Version 5.0 and subsequently 5.1 and 5.2 of the Underground Transmission Workstation (UTW) (1019980)
• Development of the EPRI Green Book (1014840)
• Successful manufacture of over 1000 feet of nano-dielectric cable for performance testing (1015926)
• Development and testing of pressurization procedures for high-pressure fluid-filled (HPFF) and high-pressure gas-filled (HPGF) cable systems (1015930)
• Increased Power Flow Guidebook (1015971), a state-of-the-science and “best practices” guidebook on optimizing the power flow capacities of underground cables and entire transmission circuits
• DTCR 5.1.1 (1022662), a computer program to calculate underground cable ratings in real time or in simulated mode
• Cryogenics Workshop (1008699) and Tutorial (1010897)
• Annual HTS Cable Technology Watch reports (1017792, 1019995)

Current Year Activities
In 2012, the projects in this research area are expected to:

• Continue development, enhancement, and validation of underground transmission design tools and models
• Apply advanced sensors to enable more cost-effective inspection and condition assessment in all cable types
• Find solutions for detecting and mitigating pipe corrosion that leads to oil leaks in fluid-filled cable systems
• Update state-of-the-science increased power flow guidebook
• Update and improving software tools and methodologies for increasing/optimizing the power capacity of underground transmission circuits
• Disseminate strategic technology and demonstration project information about superconducting technologies and coordinating with industry and government stakeholders as they seek to commercialize the technology

Estimated 2012 Program Funding
$2.5M

Program Manager
Steven Eckroad, 704-595-2717, seckroad@epri.com
Summary of Projects

<table>
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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P36.001</td>
<td>Design, Construction and Operation of UT Systems</td>
<td>This project provides tools, guidance, and resources for the planning, design, construction, operation, and maintenance of underground transmission systems.</td>
</tr>
<tr>
<td>P36.002</td>
<td>Extruded Dielectric Cable Systems</td>
<td>This project provides greater understanding of performance factors, design procedures, and improved inspection tools, and techniques to enhance the viability and operation of extruded dielectric cable systems.</td>
</tr>
<tr>
<td>P36.003</td>
<td>Laminar Dielectric Cable Systems</td>
<td>This project provides understanding of cable degradation and life-limiting factors, effective methods for maintaining the integrity of cable system components, and tools and techniques for inspection to enhance reliability and manage the life cycle of laminar dielectric cable systems.</td>
</tr>
<tr>
<td>P36.004</td>
<td>Cable Dynamic Rating and Increased Power Flow Guidebook</td>
<td>This project provides state-of-the-science reference and training materials for optimizing and increasing power flow through underground cables and entire transmission circuits. It also provides software tools to optimize power transfer capabilities in real-time for predictive assessments and for performing off-line rating studies.</td>
</tr>
<tr>
<td>P36.005</td>
<td>Develop and Deploy Superconducting Technologies</td>
<td>This project supports hardware demonstrations, disseminates vital technology development information, and promotes informed interaction among all potential participants in the developing market for superconducting power solutions.</td>
</tr>
</tbody>
</table>

P36.001 Design, Construction and Operation of UT Systems (063283)

Key Research Question

To satisfy performance-driven expectations from investors and customers, energy companies require research results and guidance for planning, design, construction, operation, and maintenance of underground transmission (UT) systems. Specific issues include the following:

- Up-to-date tools for planning, life-cycle costing, and design
- Considerations when comparing underground and overhead transmission options
- Safety practices in construction, operation, and maintenance
- Quality installation methods and materials
- Low-cost and effective construction and installation techniques
- Proper system characterization to support protection and control
- Lessons learned and failure information from system design, construction, operation, and maintenance
- Strategies for timely replacement of aged UT systems

As pressure for constructing more underground transmission lines increases, these issues have become more prominent at all stages, from planning and decision-making to long-term, reliable, and safe operations.

Approach

To address the industry issues and provide adequate tools and information, this project will capture and apply industry knowledge, enhance and validate existing solutions, and develop new tools and technologies by undertaking key tasks in a broad range of activities, such as the following:
• Identify and document best practices in planning, design, construction, and operation
• Determine and develop effective calculation and measurement methods
• Evaluate current technologies, requirements, and limitations of transmission cable system configurations
• Develop guidelines and specification recommendations for assuring quality installation
• Identify gaps and opportunities for innovative tools and methods
• Develop and validate new technologies and knowledge in effective inspection, monitoring, and maintenance

Impact
The design, construction, and operation tools and methods developed through this project may help members:
• Make more informed decisions in planning new transmission lines
• Improve efficiency in UT system design
• Improve productivity and quality in UT system construction
• Reduce overall installation, construction, operation, and maintenance costs
• Improve system reliability and safety
• Assess conditions of existing lines and plan timely replacements

How to Apply Results
Underground transmission engineers, designers, and managers can use the tools, methods, and technologies developed in this project to more effectively plan, design, operate, and maintain their UT systems for the benefits described above. Industry knowledge captured in this project can be applied to mitigate the impacts of an aging workforce and facilitate the training of a new generation of technical staff or the reassignment of existing staff.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td><strong>Electrical Safety Practices of Underground Transmission Systems:</strong> A conclusion to efforts begun in 2010 and continued in 2011 that focus on industry electrical safety issues in grounding, induced voltage, and current. Results of the three-year project will be documented in a final Technical Report that also will include evaluation of uniformity, effectiveness, and viability of current utility safety practices and identification of innovative approaches to improve safety.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Underground Transmission System Protection:</strong> A new multi-year investigation of challenges and experiences of system protection for underground and hybrid overhead/underground transmission lines and development of effective methods to calculate and measure circuit parameters of underground transmission cables and circuits both with increasingly complex construction configurations. Interim results will be documented in a Technical Update.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Guide for Specifying Quality Installation of Transmission Cable Accessories:</strong> Research to develop a greater understanding of installation and assembly issues of transmission cable splices and terminations, to investigate and identify root causes of accessory failures, and to evaluate practices and procedures for commissioning and diagnostic tests and inspection techniques for quality installation. This is a new, two-year task to produce a guide for specifying quality installation of transmission cable accessories. In 2012, the interim results will be documented in a Technical Update.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
**UT Workstation: Functional and Technical Enhancements:** Continuation of work begun in 2011 to implement a new module that calculates induced voltage and current and estimates ground potential rise in splice vaults. UTW Version 6.1 will be released.  

**Planned Completion Date:** 12/31/12  
**Product Type:** Software

**Pulling of Extruded and Laminar Dielectric Transmission Cables:** Investigation of current and innovative transmission cable pulling/pushing technologies, requirements, and limitations for different cable configurations, especially for long distance cables. This product will be incorporated as an appendix into the EPRI *Underground Transmission Cable System Construction and Installation Practices Manual* (EPRI 1019982) and the updated *Manual* delivered as a Technical Update.  

**Planned Completion Date:** 12/31/12  
**Product Type:** Technical Update

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### Future Year Products

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<tr>
<td><strong>Underground Transmission System Protection:</strong> Continuation of the study begun in 2012 to provide cable engineers with adequate tools and information to support their company's protection engineering department</td>
<td>12/31/13</td>
<td>Technical Update</td>
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</table>

**Guide for Specifying Quality Installation of Transmission Cable Accessories:** Continuation of the effort begun in 2012 to develop guidelines and specification recommendations for quality assurance of cable accessory installation.  

**Planned Completion Date:** 12/31/13  
**Product Type:** Technical Report

**Underground Transmission Vault Inspection Using Robotic Techniques:** Building on work funded by EPRI's Technology Innovation program, an investigation of an underground transmission vault inspection technique using a track/rail system installed or retrofitted within the vault. Various concepts would be explored such as optimal inspection path, rail design and material, and robotic inspection capabilities (for example, optical image and infrared temperature measurements).  

**Planned Completion Date:** 12/31/13  
**Product Type:** Technical Update

**Life-cycle Costing of Underground Transmission Systems:** Identification and assessment of approaches and influential components for life-cycle cost analysis of UT systems. The results would be used to improve life-cycle costing models and to expand the costing functionality in Underground Transmission Workstation.  

**Planned Completion Date:** 12/31/13  
**Product Type:** Technical Update

**Database on Lessons Learned in Underground Transmission Design, Construction and Operation:** A database to gather information from utilities, manufacturers, contractors, and consultants on lessons learned in planning, design, construction, installation, and testing. The database would include a search engine for the lessons learned in key phases of an underground transmission cable project. It may also include case studies on, and analysis of, cable failures in North America.  

**Planned Completion Date:** 12/31/13  
**Product Type:** Technical Update

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### P36.002 Extruded Dielectric Cable Systems (062105)

**Key Research Question**

Extruded dielectric (ED) cable systems at extra-high voltages (EHV) are a new and growing feature of North American underground transmission systems. At the same time, utilities are increasingly relying on new ED systems at all voltages to meet growing demands for new underground transmission. The growing installed base of ED systems presents challenges to utility planners, engineers, and operators that must be adequately addressed.
met in order to provide assurances that the performance and longevity of ED cable systems will be at least as
good as the proven fluid-filled systems that have historically been the backbone of the U.S. underground
transmission system. Research issues that are key to developing that assurance include the following:

- Improved materials and designs for increased capacity in constrained transmission corridors
- Solid engineering-based design and installation procedures to accommodate mechanical as well as
electrical requirements
- Effective methods for acceptance testing and real-time condition assessment
- Better understanding of cable system aging and failure mechanisms

**Approach**

This project investigates and seeks to improve new materials, equipment, and methods for HV and EHV
extruded dielectric (ED) cable systems. Solutions would be applicable to designing, selecting, installing,
commissioning, testing, operating, and maintaining an overall ED system. The project is task driven, as
prioritized by members and available funding year by year. The project will answer the key research questions
and address the industry issues for ED cable systems through the following types of activities:

- Laboratory testing to validate engineering models or to demonstrate capabilities of commercially available
  or prototype diagnostic equipment
- Development of field procedures specific to ED system for maintenance and operation
- Establishment of engineering guidelines, methods, and best practices
- Development and evaluation of innovative tools, methods, and technologies for inspecting and assessing
  the condition of ED cable systems (for example, advanced sensors and on-line diagnostics)
- Innovative product and materials development

**Impact**

Project research will produce new materials, devices, and methods that may substantially improve the ability of
extruded dielectric HV and EHV cable systems to meet system reliability, maintainability, and safety
requirements and contribute to the establishment of technical design standards that can help extend the life of
these systems.

- Laboratory testing may validate and improve theoretical understanding of the behavior of ED cables,
  which would support improved specifications and standardized designs leading to higher reliability, fewer
  customer outages, and lower lifetime system costs.
- Greater understanding of the implications of high-temperature operation may help achieve desired
  reliability and possibly increase transmission capacity at lower additional cost to customers.
- Development and deployment of advanced sensors and inspection techniques may reduce maintenance
  costs, improve utility operations staff effectiveness, and increase system reliability.
- Development and effective application of new materials may significantly reduce the initial and lifetime
  costs of UT.

**How to Apply Results**

Underground transmission engineers, designers, and managers can use the guidelines, methods (including
software), and technologies developed or assessed in this project to improve productivity and reduce the costs
of designing, installing, commissioning, testing, operating, and maintaining extruded dielectric cable systems.
Engineers will use improved understanding of the behavior of XLPE cable under normal and emergency loading
scenarios plus analytical or software-based tools to achieve effective, economical duct and vault designs.
Operators and maintenance departments will deploy new sensors and tools to obtain real-time and near real-
time information on cable system health. Planners will take advantage of smaller-diameter, longer-lived nanodielectric cables to provide additional options for increasing transmission system throughput and extending
cable life.
### 2012 Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Experimental Verification of Thermo-Mechanical (TM) Models for Extruded Dielectric Cables in Ducts and Pipes:</strong> This is an ongoing multi-year project begun in 2009. Experimental test rigs installed at EPRI's Charlotte laboratory to produce distress in XLPE cable samples in ducts and pipes will be utilized to verify existing models and develop understanding of system design fundamentals. The deliverable in 2012 will be an interim report documenting the results of initial testing using the rig.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
| **More Efficient and Effective Commissioning Tests:** Field testing using very low frequency (VLF) sources has become accepted practice for medium-voltage cables. This technology is starting to be implemented at higher voltages for transmission cables. This product would report on research into topics such as the following:  
- State-of-the-art for available VLF sources at higher voltages  
- Relationship between applied test voltage at very low frequency, test duration times, and ability to identify defects  
- Correlation between partial discharge measurements taken with more traditional resonant test sets and VLF for transmission applications  
Interim results of this new, two-year project will be documented in a Technical Update. | 12/31/12 | Technical Update |
| **Advanced Sensors and Inspection Techniques for Extruded Dielectric Transmission Cable Systems:** Research and development of advanced sensors and monitoring techniques for on-line inspection of cable system condition and operational status. This multi-year project begun in 2010 will include field trials on a host utility circuit to evaluate commercial diagnostic technologies and determine research needs. A Technical Update report will document interim results. | 12/31/12 | Technical Update |

### Future Year Products

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<tr>
<td><strong>Advanced Sensors and Inspection Techniques for Extruded Dielectric Transmission Cable Systems:</strong> Continuation of a study of advanced sensors and monitoring techniques for on-line inspection of cable system condition and operational status.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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</tbody>
</table>
| **Advanced Use of Integral Fiber Optic Cables in Extruded Dielectric Cable Systems:** Prior EPRI research indicates that fiber optic cables integrated within extruded dielectric cables or outside the sheath for applications beyond temperature monitoring may be used to assess transmission cable health by monitoring electrical, mechanical, or thermal behaviors. This product would investigate and report on the fiber optic system design and implementation. Research areas include the following:  
- Method/design for PD measurement and fault location  
- Design of suitable opto-electronics for novel use  
- Methods for effective detection of fiber damage during installation and operation  
This is the first year of a multi-year project that may ultimately result in development and/or validation of new diagnostic tools. | 12/31/13 | Technical Update |
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<tr>
<td><strong>Experimental Verification of Thermo-Mechanical (TM) Models for Extruded Dielectric Cables in Ducts and Pipes:</strong> This product will deliver a final report on the validation of EPRI TM Models for Extruded Dielectric Cables in Ducts and Pipes, using experimental test rigs installed at EPRI's Charlotte laboratory to produce distress in XLPE cable samples in ducts and pipes.</td>
<td>12/31/13</td>
<td>Technical Report</td>
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</tbody>
</table>
| **More Efficient and Effective Commissioning Tests:** Field testing using very low frequency (VLF) sources has become accepted practice for medium-voltage cables. This technology is starting to be implemented at higher voltages for transmission cables. This product would report on research into topics such as the following:  
- State-of-the-art for available VLF sources at higher voltages  
- Relationship between applied test voltage at very low frequency, test duration times, and ability to identify defects  
- Correlation between partial discharge measurements taken with more traditional resonant test sets and VLF for transmission applications  
This is the final year in a two-year project; a final report will be delivered. | 12/31/13               | Technical Report   |
| **EHV XLPE Cable Workshop:** This task is a workshop to inform and help utilities apply results reported by EPRI in *Cable System Technology Review of XLPE EHV Cables, 220 kV to 500 kV* (2002) and *Mechanical Effects on Extruded Dielectric Cables and Joints Installed in Underground Transmission Systems in North America* (2004). Development and deployment experiences of XLPE transmission cables in recent years will be addressed in the context of these reports. Lessons will be drawn for application to current or planned cable systems. | 12/31/14               | Technical Update   |
| **Guidelines for Thermo-mechanical Design of Extruded Dielectric Cable Systems:** This task will build on previous EPRI work on TM behavior of ED cables in ducts, pipes, and manholes. It will provide a concise source of practical engineering knowledge to help cable engineers successfully design ED cable systems with respect to TM effects in all common installation configurations. For various cable types, recommendations would consider design factors such as duct/cable diameter ratio; vault dimensions as a function of cable type, joint dimensions, and relative duct/pipe diameter; cable and joint orientation in vault; cable and joint clamp spacing and clamp design, including non-axial-symmetric forces; and cable and joint clamp type and dimensions. | 12/31/14               | Technical Report   |

**P36.003 Laminar Dielectric Cable Systems (063284)**

**Key Research Question**

Much of the installed UT infrastructure in North America is made up of laminar dielectric cable systems: high-pressure fluid-filled (HPFF), high-pressure gas-filled (HPGF), and self-contained fluid-filled (SCFF). Most of these systems have performed well, surpassing their original design life expectations. However, the growing age of many of these assets is a cause for concern, in some instances related to system integrity. Replacement costs for laminar dielectric cable systems are high and the consequences of electrical failures or cable system fluid leaks due to pipe corrosion are significant. Research is needed to enhance the understanding of the corrosion mechanism and improve detection; develop inspection and monitoring techniques to assist in operations, maintenance, and replacement strategies; and better understand the thermo-mechanical behavior of cables in pipes.
Approach

This project will investigate and develop new equipment, methods, and procedures for laminar dielectric cable systems. Efforts will focus on life extension, improved reliability, reduced operation and maintenance costs, and improved support for asset replacement decision-making protocols. The project is task driven as prioritized by members and available funding. Research will be directed to one or more of the following areas:

- Pipe-type cable system corrosion research, to include the following: improved understanding of coating disbondment in older pipes; impact of pipe environment (internal and external) on corrosion; and improved methods of detecting and preventing corrosion.
- Condition assessment of laminar dielectric cable systems, to include the following: characterization of new approaches and tools for dissipation factor, fluid condition, or other effective assessment methods; development and validation of sensors, digitizers, recorders, and telemetry systems to deliver distributed, near real-time in-situ data during on-line monitoring; and fiber-optic and semiconductor sensor technology.
- Leak detection in HPFF and SCFF cables, to include novel methods for economical, easy-to-use, and rapid leak detection. Research will focus on new inspection techniques or tools to give near real-time results at very low levels of leak rate or lost volume.
- Thermo-mechanical bending in HPFF cable systems, to include research into understanding and predicting distress in pipe-type cable systems, including the possibility of diagnostic methods to detect cable distress at an early stage. Research may include development of experimental protocol and testing of sample cables to replicate, accelerate, and detect cable deterioration. Research will follow a path similar to that taken for extruded dielectric cables (see Project 36.002).

Impact

This research will produce new understanding, methods, and tools that could substantially improve the ability of engineers and planners to assess the condition of laminar dielectric cable systems and take proactive steps in operating and maintaining these systems to extend asset life and prevent unexpected outages.

- Better understanding of potential failure mechanisms (such as pipe corrosion or thermo-mechanical behavior) and prevention procedures may result in longer asset life, reduced customer outages, improved customer satisfaction, and lower operations costs.
- Real-time monitoring of aging cable system assets may lead to increased asset utilization, maintenance intervention prior to spontaneous failure, higher reliability, and lower repair costs.
- New inspection techniques and tools may increase staff productivity and reduce overall maintenance costs.
- Rapid detection of fluid leaks may improve environmental responsiveness and public safety and reduce repair times and costs.

How to Apply Results

Underground transmission engineers, designers, and managers can use the knowledge base, guidelines, methods, and technologies developed in this project to improve productivity and lower the costs of operating, maintaining, and extending the life of laminar dielectric cable systems. Reliability and safety can be enhanced and asset replacement strategies improved. Maintenance personnel will make effective use of staff time and budget resources by applying new inspection methods and monitoring technology. Planners will learn where to apply selective upgrades and retrofits through better understanding of the relative condition of their asset fleet as well as where, and under what circumstances, cable systems are most susceptible to damage. Members may apply the knowledge of corrosion mechanisms and detection to fine-tune the monitoring of their systems to enhance public and environmental safety.
## 2012 Products

<table>
<thead>
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<th>Product Title &amp; Description</th>
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</thead>
<tbody>
<tr>
<td><strong>New Techniques for On-line and Off-line Condition Assessment of Laminar Dielectric Cable Systems:</strong> A continuation of an evaluation and characterization of new techniques for condition assessment of laminar dielectric cables begun in 2011. Techniques may include both off-line and on-line systems. On-line system evaluations would incorporate the sensors, telemetry, and communications necessary to facilitate near real-time monitoring of cable systems. Interim results will be documented with a Technical Update report.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Corrosion Effects and Prevention in Pipe-Type Cable Systems:</strong> A continuation of the multi-year project begun in 2011 utilizing EPRI's recently installed, state-of-the-art pipe-type cable corrosion laboratory in Charlotte. Research will lead to a better understanding of coating disbondment in older pipes, corrosion occurrence and rates as a function of pipe environment (internal and external), and improved methods of detecting and preventing corrosion in pipe-type cable systems. A technical update will document interim results.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Guide to Condition Assessment Techniques for Laminar Dielectric Cable Systems:</strong> This is an update of popular but dated EPRI guidelines for condition assessment techniques based on the most recent industry knowledge. Hardware, application, and limitations of various techniques such as dissipation factor and dissolved gas analysis will be discussed.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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## Future Year Products

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<tr>
<td><strong>Impact of High Dissipation Factor of In-service Fluid on Cable Insulation Performance:</strong> Investigation of the significance and impact of high-dissipation factor of in-service fluid on fluid-filled cable, joint, and termination insulation performance, including its effects on dielectric losses, potential heating, breakdown strength, and life expectancy. Interim results of the research will be documented in a technical update.</td>
<td>12/31/13</td>
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</tr>
<tr>
<td><strong>Corrosion Effects and Prevention in Pipe-Type Cable Systems:</strong> A continuation of the multi-year project begun in 2011 utilizing EPRI's recently installed, state-of-the-art pipe-type cable corrosion laboratory in Charlotte. Research will lead to a better understanding of coating disbondment in older pipes, corrosion occurrence and rates as a function of pipe environment (internal and external), and improved methods of detecting and preventing corrosion in pipe-type cable systems. A technical update will document interim results.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>New Techniques for On-line and Off-line Condition Assessment of Laminar Dielectric Cable Systems:</strong> Evaluation and characterization of new techniques for condition assessment of laminar dielectric cables. Techniques may include both off-line and on-line systems. On-line system evaluations would incorporate the sensors, telemetry, and communications necessary to facilitate near real-time monitoring of cable systems. This task is a conclusion of work begun in 2011 and will be documented with a Technical Report.</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>
**New Insulating Fluids for HPFF and SCFF Cable Systems:** Research building on past EPRI work on a functional test matrix for fluid evaluation (EPRI Reports 1007615, 1001923, and TR-111722), as well as current EPRI research on alternative transformer fluids (Program 37). Investigate and assess new dielectric fluids from natural and synthetic hydrocarbons with improved environmental properties, as well as sources to provide alternatives to commonly used cable insulating fluids. New fluids would be expected to ensure high biodegradability in accordance with international standards, even in a low-oxygen environment such as underground. The scope of the task would include identification and development of potential fluids and laboratory studies using paper tapes as well as cable models and field trials.

Planned Completion Date: 12/31/14
Product Type: Technical Update

**Development of HPFF & XLPE Transition Joints up to 345 kV:** Transition joints are needed to connect laminar insulation cables to extruded dielectric systems at voltages up to 345 kV. CIGRE WG B1.24 is in a process of defining test regimes for transition joints and associated cables for type, routine, sample, and after-laying tests. Planned research may include the following:

- Investigate and assess prior EPRI/ConEd/ABB transition joint development work
- Work with cable accessory manufacturers to develop and/or field test transmission joints that would be smaller, cheaper, and more reliable for voltage levels up to 345 kV.

Interim results will be documented in a technical update report.

Planned Completion Date: 12/31/14
Product Type: Technical Update

**Test Rig for Experimental Study of TM performance of HPFF Cables:** This multi-year task will develop experimental protocols and test rig designs to support improved understanding and development of predictive diagnostics for “in-pipe” thermo-mechanical bending events in pipe-type cable systems that may lead to cable failure.

Planned Completion Date: 12/31/15
Product Type: Hardware

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**P36.004 Cable Dynamic Rating and Increased Power Flow Guidebook (069263)**

**Key Research Question**

The demand for electric power over transmission circuits is increasing faster than transmission assets can manage. This trend has pushed the capacity of many existing transmission circuits to their design limits. In addition, much of the grid has already aged beyond its original design specifications. These issues are impacting the grid with an increasing number of bottlenecks and other congestion and reliability problems. Power companies are realizing that the electric power infrastructure requires attention, and there is a need to identify methods and obtain tools for delivering more power through their existing assets.

**Approach**

In order to meet the research needs, EPRI will do the following:

- Develop software tools and methodologies related to the design, engineering, system planning, and operation of underground transmission cables (and other transmission circuit components)
- Investigate and document information on the state-of-the-science and best-practices on increasing and optimizing power flow through existing assets
- Identify, develop, and document information on improvements in applications, thermal models, instrumentation, secure telemetry, and case studies
- Develop training and technology transfer activities and tools, such as tutorials, guides, workshops, and conferences, in parallel with the research and development work.
This project focuses on underground cables and is executed in coordination with corresponding projects for overhead transmission lines (Project P35.013) and substation equipment (P37.018). Feedback from EPRI member engineers, operators, designers, and planners will be sought during advisory meetings and workshops to identify future improvements.

Application of the R&D products that result from this project will aid power companies to more fully utilize their existing assets more economically and with continued reliability, safety, and public acceptance.

Impact
The results from this project will provide the tools and information needed by power companies to identify and implement increased power flow strategies for their specific needs and with continued reliability, safety, and public acceptance. These include the following:

- Guidance for experienced technical staff as well as reference and training materials for the next generation of power industry technical leaders
- Increase and optimize power flow through cables and entire transmission circuits
- Defer capital expenditures and new construction
- Improve transmission circuit reliability and safety
- Optimize energy transactions through rating forecasts
- Ride out emergency situations safely and reliably
- Avoid unnecessary system outages

How to Apply Results
Transmission engineers, operators, planners, researchers, and information technology (IT) personnel will use the computer programs and methodologies of this project to increase and optimize the ratings of their circuits. Software products can be applied for the benefits described above, and the methodologies on how best to apply all results can be obtained through EPRI guidebooks, reports, and training materials.

Members can use delivered reports as a reference source and guide for implementing increased power flow strategies and for training their engineers in increased power flow technologies. Reports and references also compare the economic benefits of increased power flow technologies, enabling EPRI members to make informed decisions when choosing increased power flow options for their specific applications. An Increased Power Flow Transmission Circuit Rating Wizard software program also will help utility engineers decide on options.

2012 Products

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<tr>
<td><strong>Increased Power Flow Guidebook - 2012</strong>: The Increased Power Flow Guidebook will continue to be augmented with more and new material on the state-of-the-science and best-practices for increasing and optimizing power flow through existing circuits. Topics specific to underground cables include the forced cooling and slow oil circulation for pipe-type cables, an updated summary on the state of superconducting cables, an expanded discussion on the use of passive heat pipes, guidance for a methodology for increasing power flow by controlled damage and replacement of hot spots, methodologies for validating amperages, and other topics recommended by the EPRI member Task Force. An Increased Power Flow Wizard will be included with the guidebook to comprise a kit.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>
### Transmission Ratings Workstation (TRW) 1.0:
The Transmission Ratings Workstation (TRW) will be initiated in 2012. This will incorporate EPRI's Dynamic Thermal Circuit Rating software (DTCR) and other ratings-related software modules under one roof. The product will be designed for performing rating studies, evaluating and optimizing static ratings, real-time ratings, and forecasted ratings for underground cables and entire transmission circuits.

**Planned Completion Date:** 12/31/12

**Product Type:** Software

### Specifications and Applications for Distributed Temperature Sensing for Cable Ratings:
This Technical Update will provide documentation on distributed temperature sensing technologies that are used for rating applications for underground cables. Topics will include types of systems, pros and cons of different systems, how they work, who the manufacturers are, what the costs and hidden costs are, how they are installed, how difficult they are to use, their accuracy and speed, how the data is integrated into supervisory control and data acquisition (SCADA) and rating programs, maintenance issues, expected reliability, telemetry and data archiving, security issues, interpreting results, and more.

**Planned Completion Date:** 12/31/12

**Product Type:** Technical Update

### Future Year Products

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<tr>
<td><strong>Increased Power Flow Guidebook - 2013:</strong> An updated version of the IPF Guidebook is planned for release in 2013, along with its Increased power Flow Wizard.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Transmission Ratings Workstation (TRW) 2.0:</strong> The Transmission Ratings Workstation software will be further improved, and a new version of the software will be delivered.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Applications of Increased Power Flow Strategies for Underground Cables:</strong> A Technical Update will be developed covering mature and novel concepts for increasing power flow of underground cables.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

### P36.005 Develop and Deploy Superconducting Technologies (102090)

**Key Research Question**

Substations of the future will likely use technologies vastly different from those applied for more than half a century. Already, both solid-state switching devices and superconductors are making their debuts in transmission and distribution substations. As transmission corridor constraints increase, studies and demonstrations are confirming the value of high-capacity high-temperature superconductor (HTS) cables in the power grid. However, the design, fabrication, and installation of superconducting equipment presents challenges, particularly in a utility substation environment. Research needs include the following:

- Hardware demonstrations to validate equipment performance and cost
- Stakeholder dialogues to increase understanding and define equipment design and testing requirements
- Guidelines for business case development to help early adopters justify investment
- Education of utility personnel: regular, timely, and informative technology status information on superconducting power system research, development and demonstration (RD&D).
**Approach**

This project supports RD&D of superconducting technologies for the power delivery system. It utilizes the extensive investments of the U.S. government, host utilities, and other organizations in emerging technology demonstrations by reporting results to inform a wider audience and solicit a larger base of support for such activities. The project answers the key research questions and addresses industry issues through a variety of information gathering and sharing activities, as follows:

- Annual technology watch reports on demonstrations and developments in the United States and worldwide of superconducting power equipment, such as high-temperature superconducting (HTS) cable, fault current limiters, and other devices
- Technology assessments and implementation guidelines
- Documentation of design specifications, installation, and operation experience
- Periodic technical conferences and stakeholder workshops as needed by technology observers, early adopters, and mature market participants to take full advantage of new superconducting systems
- Participation in stakeholder dialogues in coordination with The Department of Energy (DOE), the U.S. Department of Homeland Security, and other institutional funders and research organizations as occasions arise, with the goal of increasing stakeholder dialogue, improving access to RD&D results, and promoting the early adoption and commercialization of superconducting power delivery technology

**Impact**

The project promotes informed business decisions related to the assessment, procurement, deployment, and operation and maintenance of superconducting assets in the power delivery system. The research in this project will produce informational materials and support stakeholder interaction and information exchange to encourage the continued development and deployment of superconducting power delivery technology. Deployment of superconducting systems could accomplish the following:

- Alleviate existing transmission corridor capacity constraints by integrating superconducting components into the transmission and distribution (T&D) system
- Reduce energy losses through the higher efficiency of superconducting cables and transformers
- Improve system reliability and security through the deployment of superconducting equipment (for example, fault current mitigation, voltage compensation, and immunity from external factors such as weather and heat)

**How to Apply Results**

This project provides transmission owners and operators with the tools to understand and evaluate the technical, economic, business, and operational issues associated with deploying superconducting technologies into the T&D system. Through economic comparisons with conventional alternatives, field performance results from demonstrations, reliability and availability assessments, and studies of the impact of superconducting equipment on system operations, members can make informed decisions on how to position themselves as this technology matures. Overall results support a range of actions, from a simple "technology watch" posture to an aggressive first-adopter strategy.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTS Cables, Fault Current Limiters &amp; Power Equipment - Technology Watch: An annual update of the series of technology watch reports on HTS power equipment. The report documents worldwide demonstration project results and technology developments and provides tutorial-like educational background for engineers and managers tracking this technology.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
### Stakeholder Workshop on Superconducting Power Equipment:

Workshop for superconducting power equipment stakeholders, including electric utilities, equipment suppliers, members of standards committees, and public/private research institutions. EPRI will seek to collaborate with research funding organizations (for example, federal organizations) in the sponsorship of this workshop. The workshop will focus on promoting commercial introduction of superconducting technology for power delivery. One or more topics will be selected from the following research issues: increasing understanding and defining equipment design and testing requirements; developing guidelines for business case development to help early adopters justify investment; and education of utility personnel.

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stakeholder Workshop on Superconducting Power Equipment</td>
<td>12/31/12</td>
<td>Workshop, Training, or Conference</td>
</tr>
</tbody>
</table>

### Future Year Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td>HTS Cables, Fault Current Limiters &amp; Power Equipment - Technology Watch: An annual update of the series of technology watch reports on HTS power equipment. The report documents worldwide demonstration project results and technology developments and provides tutorial-like educational background for engineers and managers tracking this technology.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>EPRI Superconductivity Conference: Bi-annual conference convening all superconductivity stakeholders, including electric utilities, equipment suppliers, members of standards committees, and public/private research institutions. Conference will provide attendees opportunities to network and will provide an international venue for reporting on current research activities and results. A proceedings CD is produced.</td>
<td>12/31/13</td>
<td>Workshop, Training, or Conference</td>
</tr>
</tbody>
</table>
Supplemental Projects

Framework for Comparison of Overhead and Underground Power Transmission (072008)

Background, Objectives, and New Learnings

Electric transmission forms the backbone of bulk power grids. An increasing number of power transmission lines are planned to meet energy supply and demand and to improve reliability of the power grids. While overhead transmission lines represent more than 98% of the total transmission circuit length worldwide, there are significant instances where lines must be placed underground (for example, for long water crossings and in dense urban areas) in spite of the increased cost of doing so in most cases. In a growing number of instances, electric utilities face the challenge of evaluating the relative merits of and choosing between overhead and underground transmission line alternatives.

A variety of factors must be taken into account to arrive at a sound engineering-based decision in planning for and building a new transmission line. However, there is no industry-established framework for identifying the relevant factors to assess or quantify their impact and to guide the planner.

The objectives of this project are to identify major factors in making comparisons between overhead and underground transmission lines, develop procedures for the comparisons (especially for utilities in North America), and demonstrate results on representative applications.

This project will establish a framework for evaluating specific transmission line options.

Project Approach and Summary

Various reports and technical brochures have been issued by state agencies, electric utilities, independent consultants, and international organizations such as CIGRE (International Council on Large Electric Systems). Many of the reports are accessible to the public and provide excellent background information on the subject.

A joint team consisting of both overhead and underground transmission industry experts will be formed. The team will work closely with utility participants to develop easy-to-use procedures for making the comparisons. The team will address key considerations in evaluating overhead versus underground transmission line alternatives, such as the following:

- Transmission line planning and impacts to existing power grids in terms of reliability, system stability, charging current limitations, losses, operation, and maintenance
- Environmental impacts in terms of right-of-way, electric and magnetic fields, lightning, storm, flood, and dig-in
- Initial and life-cycle cost estimation

The team will develop case studies to demonstrate the concepts and procedures.

Benefits

The project will benefit the public to ensure that relevant factors are taken into account in planning new transmission lines.

The project will benefit funders by providing objective information, evaluation methods, and factual positions to regulatory agencies, local constituencies, the public at large, other utility companies, and other interest groups.

The project seeks to accomplish the following:
- Optimize both power system reliability and construction and operation cost
- Lead to better understanding of unique attributes of overhead and underground transmission alternatives
- Lead to better understanding of factors when comparing overhead and underground power transmission
Quality Guidelines for Grouting Procedures for Large Casings (072009)

Background, Objectives, and New Learnings

Underground transmission cables are most commonly installed in urban areas where overhead construction is not feasible or practical. Congestion constraints from traffic intersections or other underground utilities can often make open trench construction difficult or impossible. This situation may lead to directional drilling of large bore holes (36+ inches diameter), also called micro-tunnels or jack-and-bore. These bores are lined with a casing, fitted with conduits for the HV cables, and grouted with concrete of specially designed thermal and structural properties for the application.

Construction of this nature is unique due to the critical requirements for thermal conductivity of the grout section, elimination requirements for voids, and structural requirements. Potential consequences of improper grouting include de-rating of HV cable circuits, overheated cables, blockage of conduits due to blow-outs, or collapse of the bore hole due to heavy traffic.

Objectives of this research will be development of guidelines for proper design and construction of large bore sections with an emphasis on grouting procedures and techniques.

Project Approach and Summary

The project will survey and analyze existing techniques for large bore drilling and grouting. Investigations may include parallel industries with similar underground construction. Prior cases of this construction method will be studied. Best practices will be highlighted and recommendations developed. Topics may include the following issues:

- Grout formulation for thermal and structural requirements
- Grouting equipment and procedures to fill casings of various materials, dimensions, and duct types
- Grout location selection
- Pumping rates and pressures
- Displacement monitoring
- Grout volume requirement calculations

Benefits

Benefits to the public include the following:

- Reduced electricity costs due to more efficient construction practices
- Improved system reliability with reduced risk of outage due to cable thermal runaway

Benefits to the funding utilities include the following:

- Risk mitigation for UG transmission projects with large bore casings
- Increased quality of HV construction methodology and practices
- Reduced risk of thermal hot spots in a bore section due to improper grouting
- Improved contractor selection criteria
Substations - Program 37

Program Overview

Program Description
This program helps substation owners enhance safety, reliability, equipment life, and performance, as well as maximize the return on asset investments despite limited resources. It offers a complete portfolio of tools and technologies such as decision support analytics and transformer monitoring. The program also includes resources such as failure databases and aging models to improve transformer and circuit breaker life management and training materials for systems operators. Program results help operations and maintenance (O&M) engineers extend equipment life, optimize maintenance costs, reduce outages, and reduce switching errors.

Research Value
This research and development (R&D) program has been grouped into two broad classes: equipment reliability and industry issues. Collectively, the goal is to develop tools, techniques, and methodologies that help improve the maintenance, specification and procurement practices, inspection, assessment, and risk-based asset management at a utility. The information provided through the collection of projects in this program will provide members with information that can help with the following:

- Extend equipment life with maintenance guidelines
- Reduce maintenance costs via condition-based maintenance
- Reduce losses via improved sulfur hexafluoride (SF₆) management
- Increase awareness of high-impact low-frequency (HILF) events and be better prepared for these events
- Implement predictive maintenance practices for reduced outages
- Reduce failures of critical assets
- Reduce switching errors, increase worker safety, and prevent outages

Approach
Electric Power Research Institute (EPRI) substation research will yield a variety of beneficial data, knowledge, and training materials to program members. This information will be delivered in a number of forms and is expected to include the following:

- Component aging models
- Equipment diagnostic and risk-assessment tools and software
- Maintenance best-practices guidelines
- Reference books, guidelines, videos and interactive "game-based" training materials, and field guides
- Industrywide failure databases
- Collaborative environments for sharing near misses and best practices

Accomplishments
In the past, the Substations program has delivered valuable information that has helped its members and the industry. Some examples include the following:

- **SF₆ Complete Library, Version 2.0**: The SF₆ Computer-Based Training Modules, Version 2.0, are a set of four CDs for computer-based training on SF₆ safety, handling, and analysis that include the impact of SF₆ on the environment.
- **Industrywide Substation Equipment Performance and Failure Database—Data, Model and Results—Electronic Media**: The electronic media provides the following information using a Microsoft PowerPoint Presentation:
  - Analytical techniques used for analyzing industry-wide data
Electric Power Research Institute 2012 Research Portfolio

- Results library using data on 11,679 in-service transformers and 1185 failure records. Two types of analysis are included:
  - Analysis to better understand component and sub-system performance characteristics - for example, tap-changers, bushings, winding failures etc.
  - Analysis to better understand transformer failure rates by family, make, model, application and age.
- Data model to assist utilities in data gathering.
- Guidelines for the Life Extension of Substation Equipment: This material was first developed in the 1990s. It was felt that the standing collection of guidelines lacked the specific guidance and procedures to form a comprehensive maintenance and life extension program. This gap was bridged through technical content review which took place between 2005-2010. The resulting report provides the rationale and technical basis to form a comprehensive maintenance, condition assessment and life extension program for transformers, circuit breakers and other substation equipment.
- Annual Switching Safety and Reliability Conference: The conference is an opportunity for managers, supervisors, and operations personnel to exchange information about switching policies and procedures that contribute to improved safety and reliability practices. The conference addresses issues ranging from detailed switching procedures and associated software (through programs for training, audits, and incident investigation) to management strategies and policies for developing error-immune procedures and for dealing with errors and responsible individuals.
- Training Materials and Field Guide for the Smart Ground Multimeter: The EPRI developed Smart Ground Multimeter (SGM) was initially developed in the early 1980s, and has evolved into a sophisticated and powerful testing device. The third upgrade of the SGM was completed in 2006. The true value of the SGM is its capability to perform a ground audit of electric power installations while the installation remains fully energized. A field demonstration of the SGM for program members was held in 2007, and a Field Guide was published in 2009. The Field Guide is intended to serve as a handy reference for technicians tasked with performing a ground grid audit. It is not meant as a substitute for the SGM Operating Manual, but rather serves as a supplement that includes basic “how-to” and practical considerations.

Current Year Activities

In the coming year, the Substations program expects to accomplish these objectives:

- Industrywide databases for substation equipment with new analysis results
- New versions of Substation Life Extension Guidelines with field guides and learning modules
- Transformer and circuit breaker aging models
- Transformer reference book (the Copper Book)
- Inspection and assessment strategies for Balance of Substation
- Circuit breaker life management and lubrication
- Development of fault current limiters to the 69-kV level
- Circuit breaker diagnostics using relay data
- Fault current management and substation grounding best practices
- Switching safety and reliability conference and practice sharing
- Management of legacy relays and integration of the next generation

Estimated 2012 Program Funding

$6.2M

Program Manager
Bhavin Desai, 704-595-2739, bdesai@epri.com
# Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P37.101</td>
<td>Transformer Life Management</td>
<td>Effective transformer life management via novel condition-monitoring techniques and new algorithms for turning that condition-monitoring data into actions.</td>
</tr>
<tr>
<td>P37.102</td>
<td>Circuit Breaker Life Management</td>
<td>This project performs research to help utilities better understand the implication of time and stress driven degradation in circuit breaker components and sub-systems. This project develops tools, methodologies, and information to enable cost-effective methods for instituting condition-based maintenance or selecting the most appropriate material, work practices and tasks. It will include high-voltage and medium-voltage (13.8-kV to 69-kV) breakers.</td>
</tr>
<tr>
<td>P37.103</td>
<td>Protection and Control</td>
<td>The project will address a set of most pressing tasks for protection and control. The research work will collaborate extensively with member utilities, vendors, research laboratories, and subject-matter experts to deliver and apply the R&amp;D results in support of utilities to solve their real world P&amp;C challenges.</td>
</tr>
<tr>
<td>P37.104</td>
<td>Substation Ground Grid Research</td>
<td>This project conducts research and develops guidelines and tools for designing and evaluating the performance of substation grounding grids and for corrosion mitigation approaches.</td>
</tr>
<tr>
<td>P37.105</td>
<td>Other Substation Equipment</td>
<td>Inspection, assessment and maintenance strategies will be developed for the balance of the substation in this project (i.e. all components not specifically handled in other projects).</td>
</tr>
</tbody>
</table>
| P37.106       | High Impact Low Frequency Events                  | This project will track the HILF-related threats to the electric power system. For each type of event in the HILF category, the state of the science will be provided in the threat itself, the vulnerability of the electric system to the threat, and the latest operational and hardware mitigation approaches. Regulatory changes and emerging compliance rules will be captured and communicated as well.  There are two associated supplemental projects:  
1. Sunburst supports the installation and measurement of geomagnetically induced currents (GIC) monitors on participants substations. The information is combined with other host sites in the project to show in real time how storms progress across the system. These results are fed back into modeling and prediction tools, such as NASA Solar Shield, and like the models being developed in the Geomagnetic Disturbance (GMD) Supplemental project to help validate and refine the models. The information gathered in the Sunburst project improves our understanding of solar storms and their coupling with the electric grid. This is fed into the ARP project to support the risk management of HILF events.  
2. Geomagnetic Disturbance focuses on education, vulnerability assessment, and mitigation of solar storms. Models will be developed to assess the response of the grid to given input scenarios, including severe storms that that led to the collapse of the Hydro Quebec system in the early hours of March 13, 1989. The project will develop assess the efficacy of mitigation strategies and hardware, and develop new operational approaches and blocking devices. The results of the GMD supplemental project will be fed back into the ARP project to help companies effectively manage the risk of solar storms on their system. |
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<thead>
<tr>
<th>Project Number</th>
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<tbody>
<tr>
<td>P37.107</td>
<td>Substations Equipment Rating</td>
<td>This project provides state-of-the-science reference and training materials for optimizing and increasing power flow through substations and entire transmission circuits. It also provides software tools to optimize power flow in real-time, for predictive assessments of power capacities, and for performing off-line rating studies.</td>
</tr>
<tr>
<td>P37.108</td>
<td>SF6 Management</td>
<td>This project helps members address SF₆ issues through improved safety, reduced SF₆ emissions, and enhanced knowledge capture and training.</td>
</tr>
<tr>
<td>P37.109</td>
<td>Fault Current Management Issues</td>
<td>This project addresses fault current management in a systematic way by investigating issues such as the impacts of fault currents on substation equipment as well as identifying new techniques to mitigate fault currents.</td>
</tr>
<tr>
<td>P37.110</td>
<td>Switching Safety and Reliability</td>
<td>This project aims to develop controls and procedures that prevent errors in power switching (both in the control room and in the field), enhance worker and public safety, and improve power delivery reliability.</td>
</tr>
<tr>
<td>P37.111</td>
<td>Risk Based Substation Equipment Asset Management</td>
<td>Analytics for Substations Asset Performance: Condition information combined with analytics based on fundamental understanding of the equipment (built, designed, operated, and maintained) are brought together to provide decision support for improved performance and risk management. Ongoing R&amp;D efforts are focused on developing condition assessment and risk mitigation algorithms to understand existing performance for transformers and circuit breakers.</td>
</tr>
<tr>
<td>P37.112</td>
<td>Industry-wide Equipment Performance Database</td>
<td>This project provides participating utilities with aggregated data and information resources, not currently available to individual utilities to assist in developing repair/refurbish/replace strategies for aging substation equipment fleets. The project collects equipment performance and failure data in a common format from many sources to establish a database that enables statistically valid analysis to better determine equipment failure rates, identify “bad actors” early, and help identify best maintenance and specification practices.</td>
</tr>
<tr>
<td>P37.113</td>
<td>Next Generation Condition Monitoring and Diagnosis</td>
<td>This project researches and documents new technologies and implementation methodologies for condition monitoring and diagnosis of substation equipment. It also aims at increasing the understanding of the physical properties associated with failure mechanisms of individual equipment.</td>
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</table>

**P37.101 Transformer Life Management (072010)**

**Key Research Question**

There is an increasing need for electricity companies to maximize the of use assets while maintaining system reliability. In this environment, management of the aging population of power transformers has become the most critical issue facing today's substation managers and engineers. Central to transformer management are effective transformer diagnostics, condition assessment, knowledge retention and transfer, aging assessment and life extension. This project addresses these key issues through focused themes and a multi-year plan of tasks to support those themes.

**Approach**

Each year, results are delivered through tasks performed to address six broad themes. The stability in the themes supports a clear multi-year plan approach:
Electric Power Research Institute

2012 Research Portfolio

- **Novel sensors**: Under this theme, EPRI conducts research on new sensors for assessing transformer condition. The research develops specialized sensor hardware to provide insights into transformer health that are not obtainable using traditional techniques—or provide a step change decrease in overall implementation costs. Research also helps members understand new emerging sensors in the marketplace—both in the utility industry and in other industries where sensor advances could be easily translated to transformers.

- **Training and knowledge transfer**: The *Copper Book*, a comprehensive transformer reference book that focuses on all aspects of transformer operation, maintenance, procurement, and life-cycle management is being developed. It is uniquely written from the perspective of a utility engineer and comprehensively addresses each phase of activity from specifications through to end-of-life. The *Copper Book* serves as a valuable training aid and guides engineers through case studies of common calculations necessary for transformer specification and management.

- **Transformer algorithm development**: Under this theme, EPRI uses the knowledge and experience gained from years of research to develop actionable information from data gathered from transformer sensors. This topic is growing in importance as more sensors send larger volumes of data from transformers in the field.

- **Transformer aging assessment**: Improved estimates of a transformer's remaining life offer significant financial and reliability benefits. EPRI is researching the dynamic behavior of new chemical markers in the oil that hold the potential for significant improvements in the accuracy of transformer life estimates—possibly even without knowledge of the history of the transformer or the oil.

- **Transformer life extension**: New research has demonstrated the possibility for continuous online filtration of oxygen and moisture with new membrane technologies that offer the potential for low cost and minimal maintenance. This would open the door for life-long filtration and corresponding life extension to the transformer.

- **Transformer forensics—linking diagnostics and maintenance with true internal condition**: EPRI research is carefully examining retired or failed transformers and relating the evidence to both transformer operations and diagnostics data. The resulting forensics library provides members with new insights into likely end-of-life scenarios for the increasing population of aging transformers.

**Impact**

- Effective transformer life management via condition-monitoring techniques and their application.
- Advances detection and analytical techniques for evaluation of partial discharges, acoustic emissions, vibration, and dissolved gasses in oil in transformers and LTGs for better decision-making.
- Through the *Copper Book*, a comprehensive collection of transformer knowledge designed specifically for utility owners and operators is available.
- Improved estimates of the remaining life in transformers.
- Extended transformer life through application of novel filtration materials and techniques.
- New insights into likely end-of-life scenarios for the increasing population of aging transformers.
- Improved decision-making on replacement or refurbishment of transformers.

**How to Apply Results**

Substation engineers, designers, and operations and maintenance personnel can use this project's results to obtain deeper knowledge about the condition of a transformer, enabling them to make decisions on the disposition of transformers without additional consultation, testing, and analysis. Results will take the form of hardware, software, and guidebooks. The hardware prototypes will be tested in utility substations—allowing for easy future adoption. Algorithms are commonly commercialized into vendor hardware—allowing for easy adoption. The *Copper Book* will be a comprehensive reference book that can be used by utility personnel responsible for all aspects of transformer operation, maintenance, procurement, and life-cycle management. It will be used as a training aid and as a repository for all pertinent information on transformer ownership.
## 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Novel Sensors for Transformer Diagnosis – latest research results and industry update:</strong> The results of this research will assist the members in selecting and applying the latest EPRI research on sensor technologies for transformer diagnostics. Furthermore, the members will also remain abreast of industry developments in the sensors area.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>EPRI Copper Book Development – Additional chapters:</strong> The members will receive all previous chapters developed to-date, plus the added chapters on Transformer Selection, Failures, Problems &amp; Investigations, Recent Industry Research Results, plus an appendix of solved equations using a case-study transformer.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Converting transformer data into action - field-proved algorithm development and library of past algorithms:</strong> Through application of the sensor algorithms developed under this work, members will be better equipped to converting the large volumes of data gathered from transformer sensors (for example, acoustic, UHF, fault gasses) into well-defined and field-proved actions.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Improved transformer aging estimations using new chemical markers:</strong> The research is identifying new chemicals (and ratios of chemicals) in the oil that can more accurately estimate the age of transformers and, thus, allow for significantly improved asset management of transformer fleets. In 2012, the research will move from the laboratory out into field trials. The technical update will allow members to apply all the results gained to-date.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Membrane technologies for lifelong oil filtration – with the ability to still track fault gasses:</strong> The research is aimed at extending transformer life by cost-effectively maintaining the oil in excellent condition (low moisture and oxygen). In 2012, the membrane technologies that were shown to be effective in the laboratory tests will be moved out to field trials. The report will allow members to quantify and apply the research findings.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Forensic library of transformers – linking diagnostics and maintenance to true internal condition:</strong> The forensics library will allow members to strongly link monitoring or maintenance performed on a transformer to the likely outcomes in life and performance. In 2012, further transformer tear-downs will be added to the library and due to the large size of the library the paper report will be converted into an interactive real-time interface.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Root cause and failure investigation guide:</strong> A field guide to answer questions on preparing for a root cause investigation and provide guidance on data to gather throughout the process. The guide also includes case studies to illustrate the approach.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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## Future Year Products

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<tr>
<td><strong>2013 update and field trial findings for novel sensors for transformer diagnosis:</strong> Field trial and laboratory updates for novel sensors</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Prototype hardware - Improved transformer aging estimations using new chemical markers:</strong> In 2013 the prototype of the field unit for aging estimation will be developed and tested.</td>
<td>12/31/13</td>
<td>Hardware</td>
</tr>
<tr>
<td>Product Title &amp; Description</td>
<td>Planned Completion Date</td>
<td>Product Type</td>
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<tr>
<td><strong>Prototype hardware - Membrane technologies for lifelong oil filtration:</strong> The membrane technologies will extend beyond the laboratory and field trials into the development of the first field prototype.</td>
<td>12/31/13</td>
<td>Hardware</td>
</tr>
<tr>
<td><strong>Updated forensics library to include the most recent tear-down data:</strong> Yearly expansion of the forensics library and refinement of the interactive user interface</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td><strong>EPRI Copper Book Development – Additional chapters:</strong> In 2013, the writing of the chapters will be complete and the complete text will be reviewed and vetted for final consolidation into the electronic kit.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
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</table>

### P37.102 Circuit Breaker Life Management (072011)

#### Key Research Question

The life-cycle performance of power circuit breakers is, to a large degree, determined by the performance of constituent materials and components. Some component deterioration (for example, linkages and interrupter) is not time dependent, while the rate of deterioration of lubricants and seals is. Together, the performance of these elements drives the requirements for maintenance and refurbishment. Despite the importance of these issues, utilities have little quantifiable data or a complete understanding of breaker material and subsystem performance to enable cost-effective methods for instituting condition-based maintenance or selecting the most appropriate work practices and tasks. This research will develop the tools, methodologies, and information to address these gaps for high-voltage circuit breakers and extend application to medium-voltage (13.8-kV to 69-kV) breakers.

#### Approach

To address these needs, this project will undertake the following:

- Characterization of aging circuit breaker components such as pumps, compressors, control valves, mechanisms and lubricants, O-rings, seals, gaskets, relays and controls:
  - Collect and analyze field-aged samples of circuit breaker components to study degradation and effective life
  - Catalogue examples or samples of utility lubrication-related problems or parts failures
  - Define and quantify substation circuit breaker lubrication technical issues
  - Characterize possible consequences on breaker performance of degraded components and lubricants (for example, slow trip, abnormal mechanism wear, compressor/pump failures)
  - Investigate the use of data from digital relays for circuit breaker diagnostics

- Assessment of industry best practices:
  - Gather information about current practices for maintaining and lubricating power circuit breaker mechanisms and equipment such as compressors, pneumatic and hydraulic systems, control relays, and switches

Combine knowledge gained about circuit breaker and related disconnect-switch lubrication to develop the following:

- A quantitative understanding of aging and deterioration rates
- Expected life of circuit breaker component materials and subsystems
- Enhanced cost-effective methods for implementing a condition-based maintenance approach
Impact

As circuit breaker maintenance intervals are extended, the risk of exceeding the useful life of individual components and subsystems increases. Increased knowledge of lubrication and components performance is expected to result in increased circuit breaker availability and reduced maintenance costs.

- More effectively utilize maintenance resources
- Avoid capital investment for replacement breakers via more effective maintenance of existing assets
- Increase reliability through improved circuit breaker operations as a result of enhanced maintenance effectiveness and better condition assessment

How to Apply Results

Project funders can use project results to implement more effective and efficient circuit breaker maintenance programs and improve their selection, specification, procurement, and application practices.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Extension Guidelines for Circuit Breakers: This reference guide is specifically designed</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>to assist the substation owners with their responsibility to operate and maintain circuit</td>
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<tr>
<td>breakers. This guide helps members initiate a new maintenance, condition assessment or life</td>
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<tr>
<td>extension program, or refine an existing one. Existing technical content is reviewed annually</td>
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<tr>
<td>and updated to reflect advancements. New sections on equipment and technologies will be added as appropriate.</td>
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<tr>
<td>New Versions of Pictorial Field Guides - Power circuit breaker component degradation assessment:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>New versions of pictorial field guides will use results from ongoing studies to characterize</td>
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<td>the aging of circuit breaker components and provide application-specific guidance in a pocket</td>
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<tr>
<td>guide format for utility field staff. Existing versions of two field guides—HVCB Lubrication</td>
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<tr>
<td>Guide and HVCB Pumps, Compressors and Control Valves—will be updated with new material.</td>
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<tr>
<td>Circuit breaker performance - failure consequences and system reliability: This product</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>builds on previous research and adds new information to summarize the results of ongoing</td>
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<td>research into characterizing possible consequences on breaker performance of degraded</td>
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<td>components and lubricants (for example, slow trip, abnormal mechanism wear, compressor/pump</td>
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<td>failures) through the following means:</td>
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<td>- Cataloging failure reports and any other information available from circuit breaker failure</td>
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<td>events and/or utility root-cause analysis</td>
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<tr>
<td>- Documenting industry practices in circuit breaker routine maintenance, diagnostic testing,</td>
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<td>and over-haul</td>
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<tr>
<td>- Initiating development of a component and sub-system failure database</td>
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<tr>
<td>Circuit breaker component and sub-system performance - analysis of field aged O-rings,</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>seals and gaskets: This product builds on previous research and adds new information to</td>
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<td>summarize the results of ongoing research:</td>
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<tr>
<td>- Updated results of laboratory tests on field-aged o-rings to understand material</td>
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<td>composition and degradation.</td>
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<td>- Record and database field measurements when o-rings are removed from the breaker flange.</td>
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<td>Perform compression set tests in the laboratory to understand rate of o-ring deformation.</td>
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<td>Use results to develop guidance on o-ring effective life. Through a multi-year effort,</td>
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<td>repeat task for different o-ring applications.</td>
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<tr>
<td>- Update prior year guidance/status update with new test results and findings.</td>
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<tr>
<td>Product Title &amp; Description</td>
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<td>Product Type</td>
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<tr>
<td><strong>Circuit breaker lubrication - assessment of field-aged bearings</strong>: This product builds on research done in 2010 and 2011 and adds new information to summarize the results of ongoing research:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<td>- Continued analysis of field aged bearings (roller, needle, and ball) from key locations in the circuit breaker operating mechanism (for example, trip latch bearing)</td>
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<tr>
<td>The 2012 report will provide a status update on methodology, underlying approach, and test results.</td>
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<tr>
<td><strong>Circuit breaker lubrication - compatibility &amp; selection: laboratory assessments</strong>: This product builds on research done in 2011 and adds new information to summarize the results of ongoing research:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>- Continued laboratory testing of field-aged grease samples to better understand material composition and degradation characteristics</td>
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<tr>
<td>- Continued long-term laboratory tests on commonly used greases (mineral oil, synthetic or fluoro-silicones) to better understand performance (aging and degradation characteristics, effect of ambient environment, compatibility issues)</td>
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<tr>
<td>The 2012 report will provide a status update on methodology, underlying approach, and test results.</td>
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<tr>
<td><strong>Field Experiences of using Relay Data for Circuit Breaker Diagnostics</strong>: This product builds on prior research and adds new information to summarize the results of ongoing research and field tests:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>- Identify and catalogue applications of interest—for example, nozzle wear for SF6 breakers or contact wear for oil breakers.</td>
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<tr>
<td>- Demonstrate application through utility field trials—ongoing trials focus on detecting &quot;slow open&quot; or &quot;slow close&quot; circuit breaker operations; it is anticipated that 2012 and future year trials will focus on developing logic and necessary setting changes for detecting nozzle wear for SF6 breakers or contact wear for oil breakers. Additional applications will be added based on feedback from the Task Force.</td>
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<tr>
<td>- Document underlying methodology, logic and relay setting changes.</td>
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<td>- Provide new information in the form of triggers and thresholds for improving condition-based maintenance.</td>
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<tr>
<td>Ultimately, the goal is to develop a knowledge base or field guide for circuit breaker diagnostics using relay data.</td>
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<tr>
<td><strong>HVCB Life Management Workshop</strong>: An annual workshop that will include tutorials on the material contained in the project's products, presentations on utility experiences, and examples of the application of the project's results.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Circuit breaker component and sub-system performance: maintenance insights for pumps and compressors</strong>: This product builds on research done in 2011 and adds new information to summarize the results of ongoing research to better understand failure modes and component degradation and to develop better guidance to understand effective life.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>- Collect and analyze field-aged samples—pumps, compressors, aged mineral oil, aged synthetic oil, aged hydraulic fluids</td>
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<td>- Performance testing of commonly used pumps and compressors</td>
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<td>- Analyze performance—mineral oil versus synthetic oil</td>
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<td>- Test field-aged samples of hydraulic fluids</td>
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<tr>
<td>- Provide status update—methodology, underlying approach, test, and analysis results.</td>
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</tbody>
</table>
## Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
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<td><strong>Life Extension Guidelines for Circuit Breakers:</strong> This reference guide is specifically designed to assist the substation owners with their responsibility to operate and maintain circuit breakers. This guide helps members initiate a new maintenance, condition assessment or life extension program, or refine an existing one. Existing technical content is reviewed annually and updated to reflect advancements. New sections on equipment and technologies will be added as appropriate.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>New Versions of Pictorial Field Guides - Power circuit breaker component degradation assessment:</strong> New versions of pictorial field guides will use results from ongoing studies to characterize the aging of circuit breaker components and provide application specific guidance in a pocket guide format for utility field staff. Existing versions of two field guides—HVCB Lubrication Guide and HVCB Pumps, Compressors and Control Valves—will be updated with new material. As part of a multi-year effort, new guides focusing on control valves, circuit breaker auxiliaries, controls, and different kinds of mechanisms will be developed.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
| **Circuit breaker performance - failure consequence and system reliability:** This product builds on previous research and adds new information to summarize the results of ongoing research into characterizing possible consequences on breaker performance of degraded components and lubricants (for example, slow trip, abnormal mechanism wear, compressor/pump failures) through the following means:  
  - Cataloging failure reports and any other information available from circuit breaker failure events and/or utility root-cause analysis  
  - Documenting industry practices in circuit breaker routine maintenance, diagnostic testing, and mechanism rebuild tasks  
  - Ultimately, developing a component and sub-system failure database | 12/31/13 | Technical Update |
| **Circuit breaker component and sub-system performance - analysis of field aged O-rings, seals and gaskets:** This product builds on research done in 2012 and adds new information to summarize the results of ongoing research:  
  - Record and database field measurements when o-rings are removed from the breaker flange. Perform compression set tests in the laboratory to understand rate of o-ring deformation. Use results to develop guidance on o-ring effective life. Through a multi-year effort repeat task for different o-ring applications.  
  - Update prior year guidance/status update with new test results and findings. | 12/31/13 | Technical Update |
| **Circuit breaker lubrication - assessment of field aged bearings:** This product builds on research done in 2012 and adds new information to summarize the results of ongoing research: continued analysis of field-aged bearings (roller, needle, and ball) from key locations in the circuit breaker operating mechanism (for example, trip latch bearing). The 2013 report will provide a status update on methodology, underlying approach, and test results. | 12/31/13 | Technical Update |
| **Circuit breaker lubrication - compatibility & selection: laboratory assessments:** This product builds on research done in 2012 and adds new information to summarize the results of ongoing research:  
  - Continued laboratory testing of field-aged grease samples, better understand material composition and degradation characteristics  
  - Wrap-up short-term and long-term laboratory tests on commonly used greases | 12/31/13 | Technical Report |
(mineral oil, synthetic or fluoro-silicones) to better understand performance (aging and degradation characteristics, effect of ambient environment, compatibility issues)

The 2013 report will document the final results, underlying methodology, and approach from the laboratory testing of commonly available greases used in circuit breakers. It will continue to report on the progress made with the tests of field-aged samples. The 2013 report also will fine-tune and enhance the methodology to assist utilities in the selection and use of appropriate circuit breaker lubricants and provide guidelines to understand lubrication compatibility. Engineers writing circuit breaker specifications can use this in order to improve the utility's specification and procurement practice.

Circuit breaker component and sub-system performance: maintenance insights for pumps and compressors: The deliverable documents the results, methodology, and approach used during the performance testing of new and field-aged pumps, compressors and samples of mineral oil, synthetic oil and hydraulic fluids. In the form of a final report, it documents failure modes, degradation mechanisms, maintenance insights on pumps and compressors and provides guidelines for developing maintenance programs.

HVCB Life Management Workshop: An annual workshop that will include tutorials on the material contained in the project's products, presentations on utility experiences, and examples of the application of the project's results

Field Experiences of using Relay Data for Circuit Breaker Diagnostics: This product builds on research done in 2012 and adds new information to summarize the results of ongoing research:
- Identifies and catalogue applications of interest—for example, nozzle wear for SF6 breakers or contact wear for oil breakers.
- Demonstrate application through utility field trials—ongoing trials focus on detecting "slow open" or "slow close" circuit breaker operations; it is anticipated that 2013 and future year trials will focus on developing logic and necessary setting changes and new applications will be added based on feedback from the Task Force. New opportunities will help fine-tune and enhance lessons learned through ongoing applications and field trials. Collectively, this will help form a growing knowledge base.
- Document underlying methodology, logic and relay setting changes.
- Provide new information in the form of triggers and thresholds for maintenance, operations, and improving condition-based maintenance.

Ultimately, the goal is to develop a knowledge base or field guide for circuit breaker diagnostics using relay data.

P37.103 Protection and Control (072012)

Key Research Question
Protection and control (P&C) equipment and systems play a crucial role in maintaining the safety and reliability of power grid throughout the energy chain. Utilities are facing increasing challenges in many areas of P&C:
- Fast evolution and growing complexity of modern P&C technology
- Emerging regulatory and compliance requirements
- Retiring P&C workforce and skill set development for new hires
- Impact of the smart grid and high penetration of renewable energy
- Aging of existing fleet of electromechanical and digital relays
The project will address the following tasks.

- **Configuration and Setting Management for Protection and Control Devices and Systems.** The complexity of managing P&C configuration and setting is a growing challenge for most utilities. The functions and capabilities of modern microprocessor-based digital relays have been significantly expanded. Digital relays can provide hundreds of settings and almost unlimited flexibility for configuring I/O, control logics, and automation functions. For those mission-critical settings and configurations, proper management and strict procedures are required not only for meeting the requirement of regulatory compliances but also for the improvement of system reliability.

- **IEC 61850 Substation Implementation.** The IEC 61850 standard, as one of the foundational smart grid interoperability standards, specifies and facilitates the data exchange and information utilization for equipment and systems in substations. The migration to the IEC 61850 standard will have a major and profound impact on today's P&C principles and practices. This task is intended to support utilities to overcome the practical issues and challenges in the field deployment of the standard. IEC 61850 Workshops will be held to promote industry-wide collaboration and facilitate experience sharing.

- **Development of Low-Maintenance Protection and Control Systems.** The traditional time-based maintenance practice for P&C systems heavily relies on human intervention. Therefore, it is error-prone, expensive, and less efficient. The enabling technologies, such as self-monitoring and self-diagnostic functions built in modern digital relays, advanced substation communication infrastructure, automatic data collection, and processing capability, make it possible for utilities to start developing condition-based low-maintenance P&C systems.

- **Mitigation of the AURORA Threat through Protection Engineering Practices.** NERC issued the AURORA alert to industry in 2010 and raised the industry-wide concern on the safety of the generator and motor fleet. One mitigation direction for the AURORA threat is to identify and fill the gap through protection engineering practices. This task aims to support utility P&C professionals to gain a good understanding of the threat and the system vulnerability, assess protective relays and hardware mitigation devices, perform lab tests, and explore the approaches for risk mitigation.

- **Life-Cycle Management of Protection, Control and Associated Data Acquisition Infrastructure.** Today's protection and control infrastructure is experiencing fundamental and revolutionary changes. In the transition from electro-mechanical relays to the state of the art digital equipment, utilities are facing the challenge in the life-cycle management of such a highly diverse P&C infrastructure. Most installed electro-mechanical devices are aging and close to their designed life cycle; meanwhile, new digital equipment tend to have a much shorter life span than its electro-mechanical predecessors. Sound strategies and approaches for life-cycle management are necessary for utilities to ensure a smooth migration from the legacy systems to the modern P&C infrastructure.

**Approach**

The following approaches will be applied to the research work:

- Develop application guides, methods, innovative technologies, and tools
- Develop proof-of-the-concept demonstration systems in laboratories
- Perform technology transfer and field deployment
- Promote industry-wide collaboration and experience sharing through workshops, task force meetings, and webcasts

**Impact**

- Improve the management of critical P&C data to minimize relay mis-operation and enhance system reliability
- Lower maintenance costs for P&C asset and minimize human error factors
- Assist utilities in the efforts of meeting regulatory and compliance requirements
- Promote cross-utility learning and industry-wide experience sharing of IEC 61850 projects and field deployment
- Obtain in-depth knowledge of AURORA vulnerability and mitigation methods by protection engineering practices
- Improve life-cycle management of P&C asset
• Keep members abreast of fast evolving P&C technologies, standards, and compliance requirements

How to Apply Results
• Utilities can selectively implement the approaches, procedures, and tools developed in technical report to improve the management of configuration and settings for a large fleet of protective relays.
• The documented industry-wide experiences of IEC 61850 field deployment can guide and support utilities in engineering, planning, and execution of similar projects.
• Utilities can follow the system design guide to develop and implement their own protection and control systems to reduce the maintenance cost and increase the reliability.
• Utility P&C professionals can apply the knowledge and approaches to mitigate the risk of AURORA threat.

2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td><strong>IEC 61850 Substation Implementation: Issues and Challenges in Field Deployment:</strong> This technical update will collect and document the issues and challenges emerging from the ongoing IEC 61850 projects across member utilities. The outcome of the research work can support utility technical staff overcome the steep learning curve and gain a good understanding of not only the IEC 61850 standard but also the real world experiences.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Configuration and Setting Management for Protection and Control Devices and Systems:</strong> This product will identify the requirements and needs, list the critical P&amp;C data/files, perform research on proper management methods and procedures, assess the state-of-the-art management tools and products to assist utilities managing the settings and configurations for a large P&amp;C fleet.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Development of Low Maintenance Protection and Control Systems:</strong> This product will elaborate the concept and requirements of developing a low-maintenance P&amp;C system, create a roadmap, assess and develop essential enabling technologies. The R&amp;D results may significantly increase the maintenance intervals as specified in the regulatory standards and improve the reliability of the overall system.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Mitigation of the AURORA Threat through Protection Engineering Practices:</strong> This product will provide literature research to assist utility P&amp;C staff better understanding the threat, generate factual research results to identify the protection gaps, recommend risk mitigation approaches and available options. The HMD (hardware mitigation device) and alternative protective relays will be studied, analyzed and evaluated in laboratory environment. The technical report will also collect and compile utility practices and experiences.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Lifecycle Management of Protection, Control and Associated Data Acquisition Infrastructure:</strong> This product will conduct a state-of-the-art review to document the “current state” of P&amp;C infrastructure; through needs assessment identify gaps and develop a methodology to assist protection and control engineers and asset managers in developing a strategy for infrastructure management, which includes legacy electro-mechanical and solid state relays and modern digital relays and associated data communication equipment. The product will be developed through multi-year research. A technical update documenting the progress will be issued at the end of each year. The 2012 technical update will focus on the needs assessment to document “current state,” identify gaps and develop a plan to address areas that need further development.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<tr>
<td><strong>IEC 61850 Substation Development: Use Cases and Success Stories:</strong> This technical update will collect and document the success stories and use cases from the IEC 61850 projects across member utilities. The outcome of the research work can help utility technical staff gain a better understanding of the actual benefits, roadmap, approaches, and cost of deploying the IEC 61850 standard in substations.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Configuration and Setting Management for Protection and Control Devices and Systems:</strong> This product will create use cases and provide a guide to assist utilities managing the settings and configurations for a large P&amp;C fleet.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Development of Low Maintenance Protection and Control Systems:</strong> This product will continue assessing and developing essential enabling technologies, provide system design guidelines, create use cases, and start building a proof-of-the-concept demo system in EPRI laboratories. The R&amp;D results may significantly increase the maintenance intervals as specified in the regulatory standards and improve the reliability of the overall system.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Mitigation of the AURORA Threat through Protection Engineering Practices:</strong> This product will provide testing results to assess the protection functions in HMD (hardware mitigation device) and protective relays, recommend risk mitigation approaches and available options from the perspective of protection engineering practices. The technical report also will collect and compile utility practices and experiences.</td>
<td>12/31/13</td>
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<tr>
<td><strong>Lifecycle Management of Protection, Control and Associated Data Acquisition Infrastructure:</strong> The product will perform R&amp;D based on the needs assessment of previous results, continue identifying gaps, and develop a methodology to assist protection and control engineers and asset managers in developing a strategy for infrastructure management.</td>
<td>12/31/13</td>
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P37.104 Substation Ground Grid Research (072013)

Key Research Question

A substation ground grid is an essential component of the substation. It must do the following:

- serve as a safety feature for any personnel who may be in the substation during a fault
- minimize hazards to the public, such as step-and-touch voltages near the substation
- provide adequate ground for substation equipment, especially control room electronics

The ground grid must be carefully designed to ensure that even the worst occurring faults will not harm the staff or the public and will not damage substation equipment. Today, substation ground grids are receiving more attention because of their advanced age and increasing fault current levels. Facilities that were designed and installed 50 or more years ago were often based on a calculated fault current from the generation sources and interconnections of that time. Although the common practice then was to base the design on a conservative calculation of available fault levels, over the years additional generation and introduction of increased power flow measures (such as high-temperature conductors) have resulted in increased fault current levels. At the same time, there are sites at which enough corrosion of the grid, damage (perhaps not immediately noticeable) due to construction and other factors, and copper theft have occurred over the decades to measurably decrease the effectiveness of the ground grid. Research is required to develop ways to refurbish grids that may have deteriorated over the years.
Approach
In the early 1980s, EPRI developed software for the design of substation grounding grids. EPRI developed the Smart Ground Multimeter (SGM), a sophisticated electronic instrument for measuring substation ground grid impedance and other parameters without requiring an outage with final enhancements being completed in 2006. Building on these accomplishments, this project conducts a study of ground grids, substation grounding designs, and substation ground surface conditions, with a focus on enhancing fault current ratings of ground grids, refurbishing deteriorated grids, and minimizing hazards within and outside the substation. This activity includes full-scale tests to verify the studies and their recommendations. Project products include data and guides on the design and construction of new ground grids with increased current ratings, ground grids to which an incremental area is being added, ground grids that must be augmented to increase their fault current rating, and the characteristics of substation ground surface finish (gravel, asphalt, concrete). The research will provide advice on when to consider the possibility of corrosion of the ground grid, what choices can minimize the degradation of corrosion, and how deteriorated grids can be detected, assessed and refurbished in the most economical manner. Results also can be used to enhance industry standards such as Institute of Electrical and Electronics Engineers (IEEE) 80, 81 and 837.

Impact
- Improve the ease and accuracy of evaluating the adequacy of installed grounding systems.
- Provide effective methods to design and install new grids, bolster grids that have deteriorated, or improve grids that need upgrading because of higher fault current levels.
- Quantify the properties of various ground surface materials (gravel, asphalt, concrete).
- Increase public safety and substation worker safety in areas adjacent to the substation via design of high-quality substation ground grids.
- Increase the quality of reference ground for substation electronic equipment to minimize mis-operations and failures.

How to Apply Results
Members can use ground grid design, maintenance, and refurbishment research results and guides developed in this project for planning new grids and enhancements to existing grids; evaluating the condition and degree of deterioration of existing grids to ensure public and worker safety and proper operation of substation electronic equipment; and developing grid repair decisions based on economics and enhancement of industry standards.

2012 Products

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<tr>
<td><strong>Grid corrosion assessment</strong></td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Corrosion of connections</strong>: This task will conduct a survey of substations that have been identified to have grid corrosion issues. Information will be sought on local substation conditions and external influences, such as soil types, drainage properties, ground water levels, external sources of ground currents (for example, aluminum smelters), and related factors that could be responsible for grid deterioration. Soil samples will be requested. Based on this information, aging tests will be designed. In future years, samples of grid elements (for example, connectors) will be installed in controlled test setups containing various soil types, then exposed to various ground current conditions, and the results will be analyzed to correlate grid deterioration with exposure parameters and to develop general guidelines.</td>
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<tr>
<td><strong>Field performance of connectors</strong>: Various connector types, designs, and technologies are available to connect ground grid elements, including compression and exothermic connectors offered by various vendors. This product will conduct an industry survey of utility experience with various connector types installed in substation ground grids.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Develop cost-effective approaches to augmenting or repairing substation ground grids:</strong> Substation ground grids may not meet performance requirements because of increasing fault currents, deterioration over time due to corrosion, damage (perhaps not immediately noticeable) due to construction and other factors, copper theft, and other issues. This product will include essential data and guides for augmenting or repairing grids to increase their fault current rating and grounding effectiveness. As an example, the guidelines may include case studies that provide percentage increase in a grid’s capability when the grid is augmented with a specific grid section, or when additional ground rods are installed.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Corrosion rates, effect of soil properties:</strong> Based on surveys, connector aging tests and analyses conducted in previous years, this product will summarize the findings in a final Technical Report and provide general guidelines and recommendations for remedial and mitigation approaches to minimize substation ground grid corrosion.</td>
<td>12/13/14</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Ground grids for HVDC substations:</strong> Many utilities are considering converting ac lines to dc and/or building new dc lines, which will require installation of dc substations. Essential data are lacking regarding grid design for dc substations. This product will help fill this knowledge gap.</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>New materials (replacement for copper) – grid, pigtails:</strong> Copper theft and deterioration (corrosion) of substation ground grids are major concerns to utilities. This product will provide an overview of alternate materials that could be used in place of copper for substation grids and will assess their performance characteristics.</td>
<td>12/31/15</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
| **“Blind study” - three audits (“as is”, “damaged”, “repaired”):** Conduct a three-stage “blind” study using the Smart Ground Multimeter:  
  • Assess the “as-is” condition of an aging (possibly damaged) ground grid  
  • Assess the condition of the grid in the same substation after unknown modifications (additional damages) are performed by the utility, without informing the researchers of the details of the modifications  
  • Assess the condition of the grid in the same substation after repairs are performed by the utility, without informing the researchers of the details of the repairs | 12/31/15 | Technical Report |

P37.105 Other Substation Equipment (065593)

Key Research Question

Increasing the reliability, safety, and life of substation equipment requires timely and effective maintenance based on accurate inspection and knowledge of equipment condition. To achieve these objectives, personnel need to understand the balance of substation equipment, their degradation and failure modes, and current industry inspection and assessment practices. Availability of new technology, coupled with a loss of institutional knowledge, increases the challenge facing substation owners. Engineering and maintenance staffs need to remain abreast of the latest inspection developments and assessment techniques to be able to select the appropriate course for their particular circumstances. In addition, field personnel need tools and training to ensure that correct and consistent decisions are made.
**Approach**

Balance of Substation includes all components and assets in the substation other than the components handled specifically in other projects, i.e. apart from transformers, circuit breakers, Gas Insulated Substations, ground grid, protection and control devices. Other components addressed include, but are not limited to: external insulation, disconnect switches (manual and motor operated), current transformers (CT’s), voltage transformers (VT’s), capacitor banks and ground switches, concrete foundations, station batteries and insulators in substations.

Ongoing R&D builds on previous research and maintains a "living" needs assessment and R&D roadmap to identify and address outstanding issues for each substation asset type.

Through laboratory testing of field-aged components, develops a better understanding of associated fundamental issues such as design, vintage and type issues, failure mechanisms, and degradation modes. In this task, work will focus on equipment of interest. Based on available funding, the Task Force will prioritize components of interest and, based on priority, sample-gathering guidelines will be provided and a test plan developed.

With appropriate effort to enhance and fine-tune, applicable research in other equipment areas can be adapted and applied to ongoing R&D in other substation equipment. One example is the impact of contamination on insulator performance.

In 2012 this project will undertake the following tasks:

- **Disconnect switches**
  - Through laboratory testing of field-aged components, develops a better understanding of associated fundamental issues such as design, vintage and type issues, failure mechanisms, and degradation modes. Work under this task was initiated in 2011, and it is anticipated that it will conclude in 2012.
  - Update maintenance, inspection and assessment guidelines for disconnect switches based on the analysis of test results.

- **Current transformers**
  - Conduct a knowledge review to document different current transformer designs in-service at utilities and their applications
  - Catalogue examples or samples of utility-related problems or parts failures. Using web-based survey, document industry practices and experiences of root-cause analysis and failure investigations.
  - Through needs-assessment identify tasks that require laboratory testing or tasks that are essential to better understand fundamental failure modes and degradation mechanism through aging tests. Develop and communicate plan.

- **Concrete foundations**
  - Assess current utility practices using a web-based survey, analyze results, document gaps, and develop a plan to communicate areas that require further development.

- **External Insulation**
  - The following topic will be addressed in 2012:
    - **In-service testing of Surge Arrestors**
      - Develop, demonstrate and document prototype test and measurement technology to effectively assess surge arrestors in the field without removing from service.
  - The following topics will be addressed in future years:
    - **Substation insulators: Resistive Glaze and RTV Coatings**
      - Document the performance and application of resistive glaze insulators and insulation treated with room temperature vulcanized (RTV) coatings.
    - **Dimensioning guidelines for applying insulators in contaminated environments**
      - Develop guidance for dimensioning external insulation and applying booster sheds and shed extenders in substations located in contaminated environments.
    - **Leakage current monitoring of insulators in contaminated environments including icing**
• Develop hardware as well as algorithms and technology application. This information will assist utilities in determining the execution of insulator maintenance such as washing.

• **Life Extension Guidelines for Other Substation Equipment**
  • Using results of testing and information gathered from utility practices, the project develops guidance for the following:
    • Provides ability to use such information to develop operation, maintenance, and diagnostic techniques for the associated equipment
    • Assists with the development of fleet management methodologies
    • Identify triggers and thresholds for initiating appropriate maintenance and condition assessment tasks
    • Identify needs for additional condition monitoring
    • Improve specification and procurement practices

**Impact**
• Reduces overall maintenance costs, projects operations and maintenance (O&M) cash flow, minimizes unplanned expenses, and maximizes the benefit and value of planned work
• Improves reliability and availability via reduced reliance on time-based maintenance by using asset health and condition analysis to determine maintenance actions
• Enables more effective use of existing infrastructure and data and efficient use of maintenance personnel to manage operational risk

**How to Apply Results**
Using project results, participants can assess equipment condition early and implement risk-informed maintenance and asset management decisions based on industrywide best practices and the most advanced techniques. Results will facilitate knowledge retention and aid in training personnel.

**2012 Products**

<table>
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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Disconnect Switch: laboratory testing and analysis of field aged samples:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>
This technical update will document results of laboratory tests performed on field-aged component and sub-system samples of other substation equipment. The objective of lab testing is to better understand the fundamental failure modes and degradation mechanisms and use this information to improve maintenance, inspection and assessment strategies. Information provided in this product will continue to build on the previous year's research.

| Life Extension Guidelines for Other Substation Equipment: This reference guide is specifically designed to assist the substation owners with their responsibility to operate and maintain other substation equipment—CT's, VT's, disconnect switches, arrestors, concrete foundations and insulators. This guide helps members initiate a new maintenance, condition assessment or life extension program, or refine an existing one. Existing technical content is reviewed annually and updated to reflect advancements. New sections on equipment and technologies will be added as appropriate. | 12/31/12 | Technical Update |
### Current Transformers: needs assessment and knowledge review
The 2012 technical update will focus on the following three topics:

- **Conduct a knowledge review to document different current transformer designs in-service at utilities and their applications.**
- **Catalogue examples or samples of utility-related problems or parts failures.** Using web-based survey document industry practices and experiences of root cause analysis and failure investigations. **Through needs-assessment identify tasks that require laboratory testing or tasks that are essential to better understand fundamental failure modes and degradation mechanism through aging tests.**

**Planned Completion Date:** 12/31/12

**Product Type:** Technical Update

### Concrete Foundations: needs assessment and knowledge review
This deliverable will assess current utility practices using a web-based survey, analyze results, document gaps, and develop a plan to explore areas that require further development.

**Planned Completion Date:** 12/31/12

**Product Type:** Technical Update

### In-service testing of Surge Arrestors
Develop, demonstrate and document prototype test and measurement technology to effectively assess surge arrestors in the field without removing from service.

**Planned Completion Date:** 12/31/12

### Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Life Extension Guidelines for Other Substation Equipment:</strong> This reference guide is specifically designed to assist the substation owners with their responsibility to operate and maintain other substation equipment—CT’s, VT’s, disconnect switches, arrestors, concrete foundations and insulators. This guide helps members initiate a new maintenance, condition assessment or life extension program, or refine an existing one. Existing technical content is reviewed annually and updated to reflect advancements. New sections on equipment and technologies will be added as appropriate.</td>
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<td>Technical Update</td>
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<tr>
<td><strong>Dimensioning guidelines for applying insulators in contaminated environments:</strong> This product will provide guidance for dimensioning external insulation and applying booster sheds and shed extenders in substations located in contaminated environments</td>
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<td>Technical Update</td>
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<tr>
<td><strong>Substation Insulators: Resistive Glaze and RTV Coatings:</strong> This product will document the performance and application of resistive glaze insulators and insulation treated with room-temperature vulcanized (RTV) coatings.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Leakage current monitoring of insulators in contaminated environments including icing:</strong> This product will provide an update on the development of both the hardware as well as the algorithms and application of this technology. This information will assist utilities in determining the execution of insulator maintenance such as washing.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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**P37.106 High Impact Low Frequency Events (072014)**

**Key Research Question**

The electric infrastructure is clearly one of society's greatest assets. With increased reliance on high-quality electric power for society's comfort, safety, and productivity, reliable delivery is of utmost importance. Electricity providers have a long history of successfully managing the traditional threats to reliability and the grid is inherently reliable. However, it is important that the industry also be mindful of a class of rare risks that have the potential to cause long term, catastrophic damage to the system. The events are called High-Risk, Low-Frequency (or HILF) events. Events in this class have rarely happened, and in some cases, have never happened. Example include geomagnetic disturbance, high-altitude detonation of a nuclear device to create electromagnetic interference, and intentional electromagnetic interference.

**Approach**

The objective of proposed research is to develop a holistic risk management approach, with specific focus on determining the appropriate balance of resilience, restoration, and protection. The 2012 research tasks include:

- Provides investigation, analysis, and strategic measures to assess the costs, benefits, and performance of various technologies and methods capable of reducing the risk of HILF-related events.
- Incorporate new study results to raise awareness and put the risks into context. In many cases this will take the form of industry white papers that describe the latest information of the risks, the vulnerability to the electric system and key equipment, and the mitigation approaches and hardware.
- Conduct an annual industry workshop to collect and share the latest information on HILF events.

As mitigating options are further considered, it is also important to note that it is impossible to fully protect the system from every threat or threat actor. Sound management of these and all risks to the sector must take a holistic approach, with specific focus on determining the appropriate balance of resilience, restoration, and protection. A successful risk management approach will begin by identifying the threat environment and protection goals for the system, balancing expected outcomes against the costs associated with proposed mitigations. This balance must be carefully considered with input from both electric sector and government authorities. Building on the inherent resilience of the system and enhancing the response of the system as a whole to unconventional stresses should be a cornerstone of these efforts.

**Impact**

Participants in this effort will have increased awareness of HILF events and be better prepared for these events, which supports improved reliability. Increased understanding of the risks will support informed decision-making with respect to optimal investment in defense.

**How to Apply Results**

Information will be provided via white papers and web casts. Members can incorporate the results into their project prioritization and risk management processes.

**2012 Products**

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Industry Report On high Impact Low Frequency Events:</strong> While some of these High Impact Low Frequency (HILF) events have never occurred and the probability of future occurrence and impact is difficult to measure, government and industry must work together to evaluate and, where necessary, enhance current planning and operating practices to address these risks. Care must be taken in consideration of mitigation approaches to maintain affordable power and to avoid unintended consequences to system reliability. This report is</td>
<td>12/31/12</td>
<td>Technical Update</td>
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designed to synthesize some of the best collaborative thinking on these risks to date and is intended to be part of an ongoing effort. The 2012 summary report of findings will focus on a class of rare risks with the potential to cause long-term, catastrophic damage to the bulk power system. It will provide a status update on one or more of the categories of HILF events at the determination of the advisory committee, such as Geomagnetic Disturbance, High Frequency Electro Magnetic Pulse, or IEMI.

**High Impact Low Frequency Events - Workshop:** An annual industry workshop will be delivered to collect and share the latest information on HILF events.  

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>High Impact Low Frequency Events - Workshop</td>
<td>12/31/12</td>
<td>Workshop, Training, or Conference</td>
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**Future Year Products**

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tr>
<td>Industry Report On High Impact Low Frequency Events</td>
<td>12/31/13</td>
<td>Technical Update</td>
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</table>

**Industry Report On High Impact Low Frequency Events:** While some of these HILF events have never occurred and the probability of future occurrence and impact is difficult to measure, government and industry must work together to evaluate and, where necessary, enhance current planning and operating practices to address these risks. Care must be taken in consideration of mitigation approaches to maintain affordable power and to avoid unintended consequences to system reliability. This report is designed to synthesize some of the best collaborative thinking on these risks to date and is intended to be part of an ongoing effort. Using result of multi-year research and development an annual summary report of findings will focus on a class of rare risks with the potential to cause long-term, catastrophic damage to the bulk power system.

**P37.107 Substations Equipment Rating (072015)**

**Key Research Question**

The demand for electric power over transmission circuits is increasing faster than transmission assets can manage. This trend has pushed the capacity of many existing transmission circuits to their design limits. In addition, much of the grid has already aged beyond its original design specifications. These issues are impacting the grid with an increasing number of bottlenecks and other congestion and reliability problems. The power industry is realizing that the electric power infrastructure requires more attention, and there is a need to identify methods and obtain tools for pushing more power through the existing assets.

**Approach**

In order to meet the research needs of the power industry in this area, EPRI will continue to:

- Develop software tools and methodologies related to the design, engineering, system planning, and operation of substation equipment (and other transmission circuit components). A Transmission Ratings Workstation (TRW) will be created, which will include several modules, including Dynamic Thermal Circuit Rating (DTCR), Power Transformer Loading analysis program (PTLOAD) and other substation equipment modules (for disconnect switches, circuit breakers, buss work etc.)
- Investigate and document information on the state-of-the-science and best-practices on increasing and optimizing power flow through existing assets.
- Develop information on improvements in applications, thermal models, instrumentation and secure telemetry. Case studies will be identified, developed, and documented.
- Provide training and technology transfer activities and tools, such as tutorials, guides, workshops, and conferences.

This project focuses on substation equipment and is executed in coordination with corresponding projects for underground cables (Project P36.004) and overhead lines (P35.013) which are also developing modules for the TRW software. Feedback from EPRI member engineers, operators, designers, and planners will be sought during advisory meetings and workshops to identify future improvements.

Application of the R&D products that result from this project will aid power companies to more fully utilize their existing assets more economically, and with continued reliability, safety, and public acceptance.

**Impact**

The results from this project will provide the tools, information, training, and guidance needed by power companies to assess and implement increased and optimized power flow strategies for their specific needs, and with continued reliability, safety, and public acceptance. These include the following:

- Guidance for experienced technical staff, as well as learning and training materials for the next generation of power industry technical leaders
- Increase and optimize power flow through overhead lines and entire transmission circuits
- Defer capital expenditures and new construction
- Improve transmission circuit reliability and safety
- Optimize energy transactions through rating forecasts
- Ride out emergency situations safely and reliably
- Avoid unnecessary system outages

**How to Apply Results**

Transmission engineers, operators, planners, researchers, and information technology (IT) personnel will use the computer programs and methodologies of this project to increase and optimize the ratings of their circuits. Software products can be applied for the benefits described above, and the methodologies on how best to apply all results can be obtained through EPRI guidebooks, reports, and training materials.

Members can use delivered reports as reference sources and guides for implementing increased power flow strategies and for training their engineers in increased power flow technologies. Reports and references also compare the economic benefits of increased power flow technologies, enabling EPRI members to make informed decisions when choosing options for their specific applications.

**2012 Products**

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<th>Product Title &amp; Description</th>
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<th>Product Type</th>
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<tr>
<td>Increased Power Flow Guidebook – 2012: The Increased Power Flow Guidebook (Platinum Book) will continue to be augmented with more and new material on the state-of-the-science and best-practices for increasing and optimizing power flow through existing circuits. The needs for the guidebook are identified by industry experts and EPRI member advisory groups. An Increased Power Flow Wizard will be included with the Platinum Book.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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**Transmission Ratings Workstation (TRW) 1.0:** The Transmission Ratings Workstation (TRW) will be initiated in 2012. This will incorporate EPRI’s Dynamic Thermal Circuit Rating software (DTCR), PTLOAD, and other ratings-related software modules under one roof. The product will be designed for performing rating studies, evaluating and optimizing static ratings, real-time ratings, and forecasted ratings for transformers and other substation equipment, and entire transmission circuits. DTCR and PTLOAD as stand-alone products will no longer exist and will be replaced with TRW.

**Planned Completion Date:** 12/31/12  
**Product Type:** Software

**Improved Thermal Models for Substation Current Transformers:** A technical update documenting analytical and experimental work on the development of improved thermal models of combustion turbines (CTs) for improved rating purposes will be released.

**Planned Completion Date:** 12/31/12  
**Product Type:** Technical Update

## Future Year Products

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<tr>
<td><strong>Increased Power Flow Guidebook – 2013:</strong> The <em>Increased Power Flow Guidebook</em> (Platinum Book) will continue to be augmented with more and new material on the state-of-the-science and best-practices for increasing and optimizing power flow through existing circuits. The needs for the guidebook are identified by industry experts and EPRI member advisory groups. An Increased Power Flow Wizard will be included with the Platinum Book.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Transmission Ratings Workstation (TRW) 2.0:</strong> The Transmission Ratings Workstation (TRW) will continue to be developed in 2013. This will incorporate EPRI’s Dynamic Thermal Circuit Rating software (DTCR) and other ratings-related software modules under one roof. The product will be designed for performing rating studies, real-time ratings, and forecasted ratings for transformers and other substation equipment and entire transmission circuits.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Proceedings of the Increased Power Flow Workshop:</strong> An IPF Workshop covering all aspects of increasing power flow will be held in 2013. This will include a session on transformer loading analysis. Proceedings of the workshop will be published.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Updated Developments on Substation Connectors Operating at Elevated Temperatures:</strong> Substation connectors are designed to operate at temperatures below that of the conductors being connected. These connectors are qualified under ANSI/NEMA CC1 Standard “Electric Power Connection for Substations,” but the standard does not address their thermal performance when operating beyond the original design temperatures. With the move by the industry to higher conductor operating temperatures, and the introduction of high-temperature low-sag (HTLS) conductors, there is a need to assess the impact on connectors. EPRI will be performing new tests on this issue, and results will be documented in this Technical Update. The report will be directed for engineers and technicians engaged in the design, installation, and inspection of connectors for substations and other electrical installations. It will serve as a useful aid to help improve specification and procurement practices.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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P37.108 SF6 Management (052021)

Key Research Question

Sulfur hexafluoride is a powerful greenhouse gas with a 100-year global warming potential (GWP) of 23,900 (it is 23,900 times more powerful than carbon dioxide). Utilities face increasing pressures in the areas of SF$_6$ emissions, safety, training, leak detection, destruction, and SF$_6$ analysis. As pressure to reduce greenhouse gas emissions grows and cost pressures continue to escalate, energy companies need focused solutions to meet these challenges.

Approach

Three broad themes guide this project’s research:

- Reducing SF6 Emissions—through application of new technology
- Improved SF6 tracking and reporting—to assist with emerging regulatory requirements
- SF6 training and knowledge transfer

The project approach is to answer important open questions through both laboratory testing and field validations—and then translate the results into solutions that are easy and cost-effective to apply in the substation.

Impact

- Reduces costly SF$_6$ emissions
- Mitigates risks of potential health hazards via safe handling techniques, tools, and guidelines
- Minimizes environmental emissions of SF$_6$
- Enhances SF6 tracking and reporting to meet emerging regulations
- Enables members to stay abreast of evolving developments worldwide

How to Apply Results

The results are designed for easy and rapid application. For example, members will have ready access to the CD-based SF$_6$ training tools, with the only requirement being a PC and a printer. Technologies for SF6 emission reduction are demonstrated to members in both the laboratory setting and in the field—allowing for easy adoption.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td>Visual Field Guide of common SF6 leak locations and sealing solutions:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>The visual field guide will allow members to efficiently track down and seal SF6 leaks in the field, while predicting emerging issues on aging breakers. The final benefit will be seen in reduced SF6 emissions and lower maintenance costs.</td>
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<tr>
<td>2012 Update: Computer-based training modules:</td>
<td>12/31/12</td>
<td>Software</td>
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<td>- SF6 Safety</td>
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<td>- SF6 Analysis</td>
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<td>- SF6 and the Environment (including updates on SF6 replacements research)</td>
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<td>- SF6 Handling</td>
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<tr>
<td>Novel SF6 capture technologies for emission reduction:</td>
<td>12/31/12</td>
<td>Hardware</td>
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<tr>
<td>Novel capture technologies will be evaluated and demonstrated in a laboratory in staged-for-field demonstrations.</td>
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</table>
**Product Title & Description**

**Planned Completion Date**

**Product Type**

**Best practices for SF6 tracking and reporting:** The best practices for SF6 tracking and reporting will share both technology solutions and case studies from member utilities. The results will help members respond to the emerging regulations on SF6 reporting.

12/31/12

Technical Update

**Future Year Products**

**Product Title & Description**

**Planned Completion Date**

**Product Type**

**2013 update to the Visual Field Guide of common SF6 leak locations and sealing solutions:** Additions of the latest leak detection and sealing results from the field

12/31/13

Technical Update

**Field tests of the prototype novel SF6 capture technologies for emission reduction:** Host utility trials of the SF6 capture concepts for both SF6 leaks and SF6 analysis

12/31/13

Hardware

**P37.109 Fault Current Management Issues (065594)**

**Key Research Question**

Utilities worldwide are experiencing increased fault current levels due to increased distributed energy sources as well as systems being operated at higher power levels than in the past. The issues related to increased fault currents include equipment failures and system outages.

**Approach**

This project addresses fault current management in a systematic way by investigating issues such as the impacts of fault currents on substation equipment, as well as identifying new techniques to mitigate fault currents. This project is divided into several segments.

2012 year tasks include:

**Fault Current Management Guidebook (the Maroon Book):** This comprehensive guidebook documents the state of the science for limiting fault currents in transmission and distribution assets. It describes possible schemes for limiting fault currents, reports on studies conducted at selected member sites to examine the impact of these schemes, and documents economic comparisons of each technology. The guidebook draws from a combination of information on other EPRI technologies, industry experts, documented case studies, and associated engineering and safety guidelines. A tutorial (course material) will be developed to directly support the guidebook. EPRI's *Fault Current Management Guidebook*, Fourth Edition, was published in 2010 and will be updated with the latest information in the future years. The future updates include best practices for coordination of substation grounding and nearby transmission structures' grounding and the associated step-and-touch potential issues and updates on new fault current limiter (FCL) technologies and their models for system studies.

**Study of Mechanical Forces in Primary Equipment at Increased Fault Currents:** This task will address calculation of mechanical forces in the substation equipment (bus work, insulators, and transformers) with initial focus on bus work with porcelain, composite, and a combination thereof. Investigation will determine whether the existing IEEE formulas for calculating mechanical forces are acceptable under increased fault current scenarios by reviewing the IEEE standards that were developed a few years ago and performing laboratory tests to validate and modify (if needed) the formulas for calculating mechanical forces. This task conducts lab and field tests to explore mechanical force levels at different levels of increased fault currents and develops...
mathematical models based on those results. It also investigates the impact of mechanical forces on equipment failure and provides recommendations regarding the level of mechanical forces that may cause equipment failures and their corresponding fault current levels.

**Development of Substation Design, Maintenance, and Operation Practices at Increased Fault Current Levels:** Existing IEEE standards for substation design will be reviewed and additional guidelines will be developed to address the design aspects of increased fault current levels. In addition, best maintenance and operation practices under increased fault current levels will be identified. Case studies in terms of best practices for fault current limiting will be developed.

**Future year tasks include:**

**Impact of Fault Currents on Protection and Metering:** Existing protection systems (such as relays and breakers) and metering systems (such as current transformers [CTs] and potential transformers [PTs]) may not function properly at increased fault current levels. This task studies the impact of different fault current levels on protection coordination, as well as on metering equipment. It will include lab and field testing with varying levels of fault currents, as well as monitoring of protection and metering equipment performance. In addition, the project develops simulation models based on the testing results and uses these models to study the impacts at sufficiently large (abnormal) fault current levels. The project documents all field test and simulation result and provides recommendations regarding the impacts and the percentage of increased fault current levels at which abnormal functions occur.

**Assessment of Fault Currents in the Existing Systems:** This issue involves calculating fault current levels in the existing systems due to increased loading and increased generation sources (both conventional and renewable type generation). This requires performing system studies with various generation and load scenarios to assess fault current levels in the existing utility power networks, and identifying the levels of increased fault current levels that may cause equipment failures.

**Application of Advanced Technologies to Manage Fault Currents:** EPRI has been developing solid-state fault current limiter and monitoring superconducting current limiter developments to address the issue of limiting fault currents. This project investigates other possible technologies to limit fault currents. The project develops concepts of new technologies for fault current limitation, develops prototypes, and then conducts field demonstrations.

**Impact**

- Avoid equipment replacement costs by reducing or eliminating equipment damage due to high fault currents
- Avoid costs due to system outages
- Realize more revenue by increasing power flows using existing assets
- Contribute to improved grid reliability by avoiding equipment damage and subsequent outages
- Increase safety in substations and on transmission corridors by avoiding equipment explosions
- Reduce overall costs of transmitting power over the grid
- Improve customer satisfaction with reduced interruptions and energy rate

**How to Apply Results**

Members can use project results to make informed decisions when choosing options for limiting fault currents. By implementing one or more of the options, participants can obtain increased power flows without damaging equipment due to high fault currents. Project members also will be able to understand whether their existing protection and metering systems are adequate at increased fault currents or whether their protection equipment needs replacement.
### 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td><strong>Calculation of Mechanical Forces in Substation Equipment</strong>: Improved methods for calculation of mechanical forces in different substation equipment will be developed and documented. The tasks include reviewing existing standards, developing algorithms and analytical formulas, and testing of some equipment to validate the analytical results.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Updated Fault Current Management Guidebook (Maroon Book)</strong>: The <em>Fault Current Management Guidebook</em> will be updated with the new information which include best practices for coordination of substation grounding and nearby transmission structures’ grounding, new FCL technology updates and models.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Best Substation Design, Operation, &amp; Maintenance Practices</strong>: Depending on the funding for this project, the scope of this deliverable will be adjusted. Initially utilities will be surveyed and IEEE standards will be reviewed to identify gaps in this area. Best practices will be developed for substation design, operation, and maintenance considering high fault current levels.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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### Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Updated Fault Current Management Guidebook (Maroon Book) &amp; Tutorial</strong>: The <em>Fault Current Management Guidebook</em> will be updated with the latest information. A Tutorial (course material) will be developed on fault current management issues that could be used by engineers in a self-study mode or in a classroom setting.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Best Substation Design, Operation, &amp; Maintenance Practices</strong>: Utilities will be surveyed and best practices will be developed for substation design, operation, and maintenance.</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Calculation of Mechanical Forces in Substation Equipment</strong>: Improved methods for calculation of mechanical forces in different substation equipment will be developed and documented.</td>
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<td>Technical Report</td>
</tr>
<tr>
<td><strong>Updated Fault Current Management Guidebook (Maroon Book) &amp; Tutorial</strong>: The <em>Fault Current Management Guidebook</em> will be updated with the latest information. A Tutorial (course material) will be developed on fault current management issues that could be used by engineers in a self-study mode or in a classroom setting.</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Impact of Fault Currents on Protection &amp; Metering</strong>: Increased fault current impacts on protection and metering equipment will be investigated.</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Fault Current Estimation in the Existing Systems</strong>: Utility case studies will be documented by estimating the fault current levels in the utility system.</td>
<td>12/31/14</td>
<td>Technical Update</td>
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<tr>
<td><strong>Advanced Technologies for Fault Current Limiting</strong>: New innovative technologies for fault current limiting will be developed and prospective technologies will be prototyped and tested in the field.</td>
<td>12/31/15</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Updated Fault Current Management Guidebook (Maroon Book)</strong>: The <em>Fault Current Management Guidebook</em> will be updated with the latest information.</td>
<td>12/31/15</td>
<td>Technical Report</td>
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</table>
P37.110 Switching Safety and Reliability (052029)

Key Research Question

Safety and reliability of the power grid are at the top of every utility’s list of concerns. To meet this challenge, personnel who prepare and review switching orders and/or perform switching must be properly trained to prevent switching errors and avoid error-likely situations. Switching errors must be prevented because they can create unexpected power interruptions to customers and hazardous situations for utility personnel and the public. Although some utilities have achieved very low error rates, others can benefit from further improvements.

Approach

This project conducts research with the goal of reducing switching errors, improving worker safety, reducing unscheduled outages, improving power quality, and enhancing operating efficiency and compliance with regulatory changes. It also sponsors a very successful and unique Annual EPRI Switching Safety and Reliability Conference to transfer research results to the utility industry. Using experts knowledgeable about the details of switching, the project analyzes data and procedures to highlight areas that might be improved and to identify industry best practices. Specific goals for 2011 include the following:

- Providing an annual update on lessons learned from incidents, including near misses.
- Continuing the development of the SS&R Reference Book
- Developing recommendations for qualification of switching personnel
- Discovering weak links in switching processes, and defining remedial and preventive strategies
- Sharing lessons learned
- Identifying safe switching work procedures that improve system integrity and worker safety
- Developing multimedia-based training materials
- Monitoring new industry trends and developments and assessing their impact on switching, as well as developing guidelines and training materials to meet the associated challenges

Impact

- Increase reliability and safety while reducing errors through best practices and guidelines for transmission and distribution switching
- Reduce worker productivity losses via implementation of appropriate switching procedures that include effective safety elements
- Promote sharing of lessons learned among peers
- Identify and develop best practices and new methods via comparisons of current practices
- Enable an open exchange of information on incidents and findings among participants via the annual EPRI Switching Safety and Reliability Conference.

How to Apply Results

Reports produced by this project serve as industry benchmarks that members can use to gauge their own performance. Studies of industry best practices provide guidance for improvements and development of error-insensitive procedure and help identify weaknesses and vulnerabilities within procedures being used. The project also sponsors the annual EPRI Switching Safety and Reliability Conference, which provides an opportunity for managers, supervisors, and operations personnel to exchange information about switching policies and procedures that contribute to improved safety and reliability. The conference is open to all interested parties.
2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tr>
<td><strong>Technology Innovation in Power Switching:</strong> In recent years, some degree of automation, innovation, and use of computer-based technologies has been introduced into power switching execution; however, no systematic process of identifying new technologies and evaluating them for suitability to switching operations has been developed. The objective of this project is to research technological innovations that could potentially be applicable to power switching and to assess their suitability for this purpose.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>EPRI Power Switching Safety and Reliability Project: Summaries of Published Reports and Conference Presentations 1996-2011:</strong> The SS&amp;R Project was initiated in 1996. This report presents brief descriptions of the publications of the EPRI Switching Safety and Reliability (SS&amp;R) Project and of the presentations at the annual EPRI SS&amp;R Conferences from 1996 (the year of the project’s inception) until 2011.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>EPRI’s Annual conference on switching safety and reliability:</strong> EPRI’s annual Power Switching Safety &amp; Reliability Conference is an opportunity for managers, supervisors, and operations personnel to exchange information about switching policies and procedures that improve safety and reliability. The Conference is open to all interested parties and covers all aspects related to power switching, including preparing switching orders, management of prints, measures to prevent errors, training, lessons learned from incidents and near-misses, any changes that you have made to improve safety or reliability, and emerging technologies and challenges. A special training seminar is normally held prior to the Conference. The seminar and several of the Conference sessions qualify for NERC Continuing Education credits.</td>
<td>12/31/12</td>
<td>Workshop, Training, or Conference</td>
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<tr>
<td><strong>SS&amp;R Reference Book chapters:</strong> The EPRI Switching Safety and Reliability project was initiated in 1996. Since then, it has produces more than 40 research reports, has contributed to reducing switching errors in the industry and has sponsored the annual SS&amp;R Conference. Recognizing the practical value of the accumulated volume of research results and conference presentations, the project plans to consolidate the aggregate knowledge under one cover in the form of a SS&amp;R Reference Book, which will also include a collection training modules on the subject of power switching safety and reliability. The SS&amp;R Reference Book, when completed in the next few years, will join the EPRI’s Color Book series of valuable reference materials.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Access Management to Switching Equipment for Field Personnel:</strong> Incident reports collected by the SS&amp;R project contain many examples inoperative locking devices and operators, switchmen, and technicians operating incorrect devices or entering incorrect energized areas. This product will review locking and interlocking systems on switching devices such as remotely and locally operated disconnects, interrupters, gates and other access points. It also will survey best practices and locking systems, such as bar code locks and remotely operated locks.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Annual SS&amp;R Newsletter:</strong> The annual SS&amp;R Newsletter is traditionally published in the spring of each year and contains a review of highlights of the previous year’s SS&amp;R Conference and preliminary information on the current year’s SS&amp;R Conference. Hard copies of the Newsletter are mailed to a large number of recipients worldwide, and electronic copies are available for download under unique PID numbers.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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</table>
## Annual SS&R Conference Brochure

The annual SS&R Conference Brochure is traditionally published in the summer of each year and introduces the program of the current year’s SS&R Conference. Hard copies of the Brochure are mailed to a large number of recipients worldwide, and electronic copies are available for download under unique PID numbers.

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## Future Year Products

### Situation Awareness in the control room

A recent review of control room design, layout, and color schemes (EPRI report 1015990) suggested changes to improve visualization and facilitate greater situation awareness for operators. This product, which is expected to take advantage of collaboration with other EPRI programs (for example, Program 39 Grid Operations), will seek feedback from control room operators regarding the proposed enhancements and will identify ways of introducing the changes that are compatible with operators’ needs.

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### Annual SS&R Newsletter

The annual SS&R Newsletter is traditionally published in the spring of each year and contains a review of highlights of the previous year’s SS&R Conference and preliminary information on the current year’s SS&R Conference. Hard copies of the Newsletter are mailed to a large number of recipients worldwide, and electronic copies are available for download under unique PID numbers.

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### Annual SS&R Conference Brochure

The annual SS&R Conference Brochure is traditionally published in the summer of each year and introduced the program of the current year’s SS&R Conference. Hard copies of the Brochure are mailed to a large number of recipients worldwide, and electronic copies are available for download under unique PID numbers.

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<td>Technical Resource</td>
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### Impact of changing grids on switching safety and reliability

Changing grid characteristics—including the use of high-temperature conductors, DTCR, distributed and non-traditional power sources, increasing fault currents, widespread use of sophisticated multifunctional electronic relays, and other developments—introduce new challenges that demand a detailed assessment of such factors on issues such as control room procedures, switching operations, qualification of operators, switchmen and technicians, and training materials. This product will identify the challenges and lay groundwork for future research to develop appropriate responses.

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### DMS (Distribution Management System) - Impact on switching

Implementation of Distribution Management Systems (DMS) is expected to have a significant impact on power switching safety and reliability. This product will identify the challenges and lay groundwork for future research to develop appropriate responses.

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<td>Technical Update</td>
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</table>
### Database of incidents and near-misses in switching

This is an ongoing project that collects information and reports on incidents and near misses in power switching. A reporting template developed in 2008 and updated in 2009 is used to gather the essential information. The searchable database will be populated annually with new information.

The reporting template is available from the EPRI project manager upon request.

**Planned Completion Date:** 12/31/14  
**Product Type:** Technical Update

### Human Operational Errors Involving Control, Relay, and Auxiliary Equipment

Several years ago, an EPRI report (1013596) described the findings of research related to human operational errors involving new smart control, relay, and auxiliary equipment. That report identified error modes and training needs for technicians servicing such equipment. This new product will build on previous work by defining appropriate barriers to prevent errors and by developing training materials.

**Planned Completion Date:** 12/31/15  
**Product Type:** Technical Report

### Technology Innovation in Power Switching

In recent years, some degree of automation, innovation and use of computer-based technologies has been introduced into power switching execution; however, no systematic process of identifying new technologies and evaluating them for suitability to switching operations has been developed.

This product will develop an roadmap for development of needed technological innovations in power switching and practical implementation into the utility operations.

**Planned Completion Date:** 12/31/15  
**Product Type:** Technical Report

### SS&R Reference Book

The EPRI Switching Safety and Reliability project was initiated in 1996. Since then, it has produces more than 40 research reports, has contributed to reducing switching errors in the industry, and has sponsored the annual SS&R Conference. Recognizing the practical value of the accumulated volume of research results and conference presentations, the project plans to consolidate the aggregate knowledge under one cover in the form of a SS&R Reference Book, which also will include a collection of training modules on the subject of power switching safety and reliability. The SS&R Reference Book, when completed, will join the EPRI’s Color Book series of valuable reference materials.

**Planned Completion Date:** 12/31/15  
**Product Type:** Technical Report

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### P37.111 Risk Based Substation Equipment Asset Management (072016)

**Key Research Question**

Best practice asset management decisions for maximizing performance and minimizing equipment life-cycle costs are based upon risks associated with actual equipment condition and historical performance. There are four key steps involved: understanding existing performance, understanding required performance, projecting future performance, and understanding how to bridge gaps. Ongoing R&D efforts are focused on developing condition assessment algorithms to understand existing performance and project future performance for transformers and circuit breakers.

**Approach**

This project conducts research with the goal of providing continually improved risk-based decision-support methodologies for substation equipment asset managers. It envisions that the development will lead to an integrated framework for asset risk assessment, mitigation and performance improvement: Analytics for Substation Asset Performance.
Developments in risk-based fleet management are addressed through the following tasks:

- Document and evaluate algorithms: Review of risk-based fleet management concepts and approaches that are developed by EPRI and others in the industry.
- Condition indices and relative ranking: Develop generic tools that utilities can apply and adapt to their own needs. The 2012 work will develop tools and document methodologies for calculating condition indices for the transformer main body and a framework to assist utilities with high-voltage circuit breaker maintenance ranking. Work on condition indices for tap changers will be started.
- Develop a roadmap for incorporating condition indices, operational requirements, and business rules into risk-based mitigation plans.
- Document utility use cases and application notes.
- Risk Mitigation and Maintenance Strategies Workshop: Transfer technology and provide training.

Impact

The research will enhance decision making confidence and results. The resulting development provides tools and methodologies that can be used by substation equipment asset managers for improved decision support including the following:

- An analytical framework for the application of asset management principles to substation equipment
- Reduces overall maintenance costs, forecasts O&M cash flow, minimizes unplanned expenses, and maximizes the benefit and value of planned work
- Improves reliability and availability via reduced reliance on time-based maintenance by using analytics based on asset health and condition analysis to determine maintenance actions
- Enables more effective use of existing infrastructure and data as well as efficient use of maintenance personnel to manage operational risk

Collectively, the developed suite of algorithms serves at the framework for Analytics for Substation Asset Performance.

How to Apply Results

Project participants will work with a group of equipment and maintenance experts to collect data that helps define performance metrics and models for relevant equipment. Funders can then use developed algorithms, key performance indicators (KPIs), and ranking methodologies in coordination with other equipment-focused projects. Funders also can use products to test and validate end-of-life models being pursued in other equipment-focused projects.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Risk based fleet management - concepts &amp; approaches</strong>: This product will review state of the science risk-based fleet management concepts and approaches that are developed either by EPRI or others in the industry. Expert systems, inference engines, knowledge-based systems and assess their suitability to model equipment performance will be documented. The 2012 report will develop a framework that will be enhanced and expanded in subsequent years through base and supplemental projects.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>
### Product Title & Description

| Substation Equipment Asset Management Practices: This product will survey and assess current industry maintenance and asset management practices and procedures, including lessons learned by utility experts, and identify gaps and issues with existing practices. Ongoing efforts focus on key substation equipment: transformers and circuit breakers. Over time, through task force feedback and needs assessment, other substation equipment areas will be identified and added. |
| Planned Completion Date | 12/31/12 |
| Product Type | Technical Update |

| Risk based fleet management: Tools & Methods: The product will deliver EPRI developed generic tools and methodology that utilities can apply and adapt to their own needs. Tools and methodologies developed in 2012 will consist of the following: |
| Tool to calculate condition indices for the transformer main body |
| Framework to assist utilities with high-voltage circuit breaker maintenance ranking |
| Planned Completion Date | 12/31/12 |
| Product Type | Software |

| Risk based fleet management: Utility Use Cases: This product will document utility experiences and results from their implementations of the transformer fleet management algorithms or circuit breaker maintenance ranking approaches or both. |
| Planned Completion Date | 12/31/12 |
| Product Type | Technical Update |

| Risk based substation equipment asset management workshop: The workshop transfers results and provides training on their application. Topics include, but are not limited to, risk assessment methodologies, maintenance strategies, fleet management analytics, application examples, and case studies. |
| Planned Completion Date | 12/31/12 |
| Product Type | Workshop, Training, or Conference |

| Substation Equipment Maintenance And Operation Experience Sharing: Utility Lessons Learned: This product will catalogue field experiences and lessons learned from utility equipment maintenance and operations experiences. |
| Planned Completion Date | 12/31/12 |
| Product Type | Technical Update |

### Future Year Products

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<th>Product Title &amp; Description</th>
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| Risk based fleet management - concepts and approaches: This product will update and add new material to prior year research. It reviews risk-based fleet management concepts and approaches that are developed either by EPRI or others in the industry. Through state-of-the-science knowledge review of EPRI and other relevant industry literature, the report will document expert systems, inference engines, knowledge based systems and assess their suitability to model equipment performance; for example, emulate expert thinking and encapsulate equipment knowledge. |
| Planned Completion Date | 12/31/13 |
| Product Type | Technical Update |

| Substation Equipment Asset Management Practices: This product will catalogue and assess current industry maintenance and asset management practices and procedures, including lessons learned by utility experts, and identify gaps and issues with existing practices. Ongoing efforts focus on key substation equipment: transformers and circuit breakers. Over time, through task force feedback and needs assessment, other substation equipment areas will be identified and added. Equipment classes surveyed will also be updated with new questions every year. |
| Planned Completion Date | 12/31/13 |
| Product Type | Technical Update |
### Product Title & Description

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<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Risk based substation equipment fleet management: tools and methods:</strong> The product will deliver generic tools and methodology that utilities can apply and adapt to their own needs. Ongoing research enhances underlying algorithms, action triggers, and thresholds. The generic tools first released in 2012 will be updated with enhanced algorithms and new versions released in 2013. Simultaneously, the underlying methodology and approach also will be updated. Generic tools also will be updated with new modules. It is anticipated that in 2013 the transformer condition index development also will include the load tap changer in addition to the main body. Likewise, a new version of the circuit breaker maintenance ranking tool will provide improved guidance for assessing a wider variety of mechanisms. Both will incorporate lessons learned from utility deployments.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Risk based substation equipment fleet management: utility use cases:</strong> This product will document utility experiences and results from their implementations of risk-based substation equipment asset management approaches, including mitigation strategies.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Risk based substation equipment asset management workshop:</strong> The workshop transfers results and provides training on their application. Topics include, but are not limited to, risk assessment methodologies, maintenance strategies, fleet management analytics, application examples, and case studies.</td>
<td>12/31/13</td>
<td>Workshop, Training, or Conference</td>
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<tr>
<td><strong>Substation Equipment Maintenance And Operation Experience Sharing:</strong> Utility Lessons Learned: This product will catalogue lessons learned from utility equipment maintenance and operations experiences.</td>
<td>12/31/13</td>
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### P37.112 Industry-wide Equipment Performance Database (060471)

#### Key Research Question

Power delivery companies can maximize their return on assets, while maintaining reliable system operations, by ensuring that equipment is not replaced before the end of its useful life. However, without historical performance data of assets with similar characteristics, this task can be difficult. The goals of this project are to design, develop, populate, maintain, and extract valuable information from an Industry Database for power transformers. This project provides participating utilities with aggregated data and information resources, not currently available to individual companies to assist in developing repair/refurbish/replace strategies for aging substation equipment fleets. The project collects equipment performance and failure data in a common format from many sources to establish a database that enables statistically valid analysis to better determine equipment failure rates, identify “bad actors” early, and help identify best maintenance and specification practices. Data models and software applications will be developed and presented to task force advisors for comment and further refinement. Associated supplemental projects may be launched to populate the IDB with historical data and develop company-specific applications.

#### Approach

This project addresses research through the following means:

- Collecting equipment performance and failure data from participating utilities to develop an industry-wide database. This database is designed to accomplish the following:
  - Enable statistically valid analysis to determine equipment failure rates and identify “bad actors” early.
  - Enable the development of other meaningful asset management and equipment performance metrics.
  - Provide members with aggregated data and information resources not currently available to individual companies.
• Provide members with information that is critical in developing repair/replace/refurbish strategies for aging substation equipment fleets.
• Developing data models for improving utility and industry historical record-keeping and software applications for analysis. These are developed and presented to task force advisors for comment and further refinement.
• Developing guidelines on approaches to analyzing the data and applying results of analysis.

Associated supplemental projects may be launched to populate the Industry-wide Equipment Performance Database with historical data and develop company-specific applications. Through supplemental project participation, members get customized deliverables that analyze their own fleet performance and provide individual utility failure rates and asset management metrics.

The transformer data collection analysis started in 2006, and now contains records on more than 20,000 power transformers. The circuit breaker database is under development. Tap changers and other substation equipment databases will be addressed in future years.

Impact
• Improve management of existing infrastructure with early risk detection and risk-informed maintenance and asset management decisions based on industry-wide equipment performance and failure data using pooled performance and condition-related data from participating utilities
• Achieve savings by using consistent data sharing and analyses based on industry standards
• Enable identification of “bad actors” early, reducing unplanned outages

How to Apply Results
This initiative provides participating utilities with data and information resources that are not currently available to an individual utility in order to assist in developing repair/refurbish/replace strategy for aging substation equipment fleets. Participants can use project results to test and validate end-of-life models, assess equipment risks, and develop risk-informed maintenance and asset management programs.

2012 Products

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<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Industry-wide Database: Power Transformers – Populated Data-Sets:</strong> The transformer data collection and analysis started in 2006 and now contains records on over 20,000 transformers. As ongoing R&amp;D validates the effectiveness of data models and underlying data, populated sub-sets of transformer performance and failure data will be released in a phased manner. This product will deliver data sub-sets and underlying data models. An interactive user interface will be provided to allow users to query data and visualize results.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Industry-wide Database: Power Transformers – Data Model &amp; Analysis:</strong> This deliverable compiles and analyzes performance and failure data of transformers, tap-changers, and transformer accessories. Results are delivered in the form of a PowerPoint electronic media presentation. The deliverable also will develop and annually update the schema for the underlying data models for efficient and effective collection of test, diagnostics, performance, and failure data for use in industry and utility database applications and performance analysis. The data model will be delivered in the form of a Microsoft Access schema file.</td>
<td>12/31/12</td>
<td>Assembled Package</td>
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### Industry-wide Database: Circuit Breakers – Data Model & Analysis:
This deliverable compiles and analyzes performance and failure data of circuit breakers. This product will develop and annually update the schema for the underlying data models for efficient and effective collection of test, diagnostics, performance, and failure data for use in industry and utility database applications and performance analysis. The circuit breaker database development started in 2010 through a utility needs assessment. It is anticipated that the concept will be prototyped in 2011 and 2012 using data from two to three utilities. The deliverable will document results of analysis and provide a status update on underlying methodology and approach in the form of a PowerPoint electronic media presentation.

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Industry-wide Database: Circuit Breakers – Data Model &amp; Analysis:</strong></td>
<td>12/31/12</td>
<td>Technical Update</td>
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### Future Year Products

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<tr>
<td><strong>New Versions of Industry-wide Database: Power Transformers – Populated Data-Sets:</strong></td>
<td>12/31/13</td>
<td>Software</td>
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<tr>
<td><strong>New Versions of Industry-wide Database: Power Transformers—Populated Data-Sets:</strong></td>
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<tr>
<td>The transformer data collection and analysis started in 2006 now contains records on over 20,000 transformers. As ongoing R&amp;D validates the effectiveness of data models and underlying data, populated sub-sets of transformer performance and failure data will be released in a phased manner. This product will deliver data sub-sets and underlying data models. An interactive user interface will be provided to allow users to query data and visualize results. The querying capability and visualization will be enhanced with new functionality as utility feedback and new data becomes available in future years.</td>
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| **New Versions of Industry-wide Database: Circuit Breakers – Populated Data-Sets:** | 12/31/13 | Software |
| **New Versions of Industry-wide Database: Circuit Breakers—Populated Data-Sets:** | | |
| As ongoing R&D validates the effectiveness of data models and underlying data, populated sub-sets of circuit breaker performance and failure data will be released in a phased manner. This annually updated product will deliver data sub-sets and underlying data models. An interactive user interface will be provided to allow users to query data and visualize results. The querying capability and visualization will be enhanced with new functionality as new data becomes available in future years. | | |

| **Industry-wide Equipment Performance And Failure Database: Application Guide:** | 12/31/13 | Technical Update |
| **Industry-wide Equipment Performance And Failure Database: Application Guide:** | | |
| This deliverable documents the underlying methodology and approach to analyze equipment performance and failure data in the EPRI database using different analytical techniques—for example, statistical analysis and trending. The objective of applying analytical techniques is to uncover performance characteristics and develop meaningful metrics. The initial versions of the application guide will focus on transformer data. Over time, new material will be added to assist users with analysis of circuit breaker, tap-changer, and other substation equipment data. | | |
P37.113 Next Generation Condition Monitoring and Diagnosis (072017)

Key Research Question
Condition monitoring of substation equipment has an inherent value based on preventing failure, maximizing future operation of the equipment, appropriately scheduling and determining the extent of inspections and maintenance, providing for personnel safety, and protecting the environment. New and emerging sensing and diagnostic technologies play a strong role in helping utilities achieve this goal. Many utilities are unaware of these technologies and how best to interpret and implement them. This project documents the latest inspection, monitoring, and diagnostics technologies for substations, as well as early adopter’s experiences, thus providing supporting industry data and research results to make these important decisions. It also researches new technologies and develops novel methodologies to help develop the foundations for improved condition monitoring strategies.

Approach
This project will take a three-tier approach.

- Continuous identification and investigation into novel condition maintenance technologies and implementation methodologies. Early adopters of new technologies will be identified and surveyed. Case studies will be written based on the approach taken and their experiences. This new knowledge will be delivered through Condition Monitoring and Implementation Database.
- One particular condition monitoring technology will be identified and investigated in depth.
- One substation asset will be tested and fundamental research performed to investigate possible diagnostic guidelines.

Impact
Monitoring can take many forms and should be applied when a cost/benefit value results from its use over alternatives without monitoring. The greatest challenge is to gather the combined benefit of sensing technologies, physical properties associated with aging mechanisms, and system integrators to develop seamless delivery of equipment condition information in an effective, efficient, and economic manner.

How to Apply Results
By being aware of the latest technologies and implementation mechanisms and having easy access to other utilities’ experiences through the database, members can improve and extend their monitoring programs. Results obtained in this project can support the development of effective business cases for substation inspection, monitoring, and diagnostics. In addition, members can further validate their business decisions by having easy access to other members’ experiences and laboratory research results designed to closely simulate the field environment.

In addition, the underlying results from the fundamental R&D can help utilities get more value from their present condition monitoring practices.

2012 Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Condition Monitoring and Implementation Database</td>
<td>12/31/12</td>
<td>Software</td>
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</tbody>
</table>

This database will contain information to help users develop and implement their condition monitoring strategy including: a) sensors and technologies presently available and the related issues which they are capable of detecting, b) condition assessment and criticality algorithms available, c) case studies documenting how other utilities have implemented the sensor or technology into their condition monitoring strategy will be documented and provided as part of the database.
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<tr>
<td>Application Guide: Monitoring of Surge Arresters:</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>This report will document the failure and degradation modes and how surge arresters may be monitored and assessed.</td>
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<tr>
<td>Condition Monitoring Technologies: Infra Red Inspection:</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>This technical update will be part of a multi-year research and testing initiative which will investigate the signatures and thresholds which indicate high risk components. The impact of environmental and operational conditions will be investigated.</td>
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<tr>
<td>Infrared Pocket Guide:</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>This guide is an update of the 2009 visual field guide to support inspection and assessment of substation and transmission line components. The guide will help readers understand what types of equipment are in substations, what normal operation is, what abnormal operation is, and why the equipment may be operating abnormally.</td>
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**Future Year Products**

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<tr>
<td>This database will continue the previous year’s efforts and expand information to help users develop and implement their condition monitoring strategy including: a) sensors and technologies presently available and the related issues which they are capable of detecting, b) condition assessment and criticality algorithms available c) further case studies documenting how other utilities have implemented the sensor or technology into their condition monitoring strategy will be documented and provided as part of the database.</td>
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<tr>
<td>Application Guide: Monitoring of Current Transformers:</td>
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<td>Technical Update</td>
</tr>
<tr>
<td>This technical update will be part of a multiyear research and testing initiative to document and record the failure and degradation modes and how CTs may be monitored and assessed.</td>
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Supplemental Projects

Solid State Fault Current Limiter Development - Phase 2 - 3 Phase, 15 kV, 1200 Amp SSCL (072018)

Background, Objectives, and New Learnings

The increase in available fault current levels due to added distributed generation and increased load has stressed many transmission and distribution substations to their limits. In some cases fault current levels are exceeding the interrupting capability of existing substation circuit breakers. This increase in fault current levels either requires the replacement of large numbers of substation breakers or the development of some means to limit fault current. By using a Solid State Current Limiter (SSCL), fault currents can be interrupted or current limited within ¼ cycle (4ms). This will allow near instantaneous breaking of bus ties in transmission and distribution substations to reduce the available short circuit current and allow existing circuit breakers to clear at lower fault current levels.

EPRI is already collaborating with DOE to develop a 15-kilovolt (kV) distribution-class, single-phase, solid-state current limiter prototype. Additional efforts are underway to develop a three-phase 15-kV distribution-class solid-state current limiter in collaboration with utilities, DOE, and California Energy Commission (CEC). After successful implementation of a 15-kV distribution-class solid-state current limiter in the field, research will be continued to develop a 69-kV transmission-class solid-state current limiter. In addition, EPRI is collaborating with the U.S. Navy and DOE to develop fault current limiters using “super-gate turn off” devices (S-GTOs) with advanced materials such as silicon carbide (SiC) and gallium nitride (GaN). The lessons learned from these collaborative projects will support fault current limiter development in 2012 and beyond. EPRI will continue to seek further collaborations with utilities, government agencies, and vendors to enhance and develop cost-effective solid-state fault current limiters.

Project Approach and Summary

EPRI has been working on the development of a transmission-class solid-state current limiter for several years. Phase 1 of the project is the development of a single-phase 15-kV, 1200A power stack for a solid-state current limiter with key functional tests being completed in the third quarter of 2011.

The scope of work for Phase 1 was to build and factory test a power stack consisting of 6 building blocks connected in series and two 6 building blocks in parallel. This single-phase power stack is rated for 1200 A and is suitable for 15-kV class applications. The testing of this power stack is for the key functionality of operational tests and current interruption.

As a multi-phase approach for this project, the second phase of the project is now proposed. Phase 2 would see the build and factory test of a 15-kV, 1200-A, 3-phase system, ready for field testing.

Benefits

- Reduce fault currents using fault current limiters mitigates equipment failures, which may lead to power outages and high repair or replacement costs
- Reduce environmental impacts by better utilization of existing power delivery infrastructure
- Relieve system congestion via better use of existing resources
- Reduce energy losses at transmission, substation, and distribution levels via improved controllability
- Improve reliability and power quality through the use of various power electronics technologies at substations and mitigate events such as momentary outages, voltage sags/surges, and harmonics

Background, Objectives, and New Learnings

The next generation substations will use advanced communication infrastructure and protocols to allow interoperability for multi-vendor intelligent electronic devices (IEDs) and provide advanced features for protection, control, and automation. The IEC 61850 standard not only enables interoperability by providing a standardized framework for substation components and communications, but also introduces new features, such as station bus and process bus, to innovate current substation practices and reduce project costs.

The IEC 61850 standard is complex and feature-rich. However, one outstanding challenge for the industry is lack of testing methodology and guideline to assist utility in implementation, testing, and maintenance of IEC-61850-based equipment and systems. The testing methodology and guideline are required not only for the purpose of conformance to the standard but also for those practical and essential applications, which include factory and site acceptance, commissioning, and maintenance testing in a field environment.

The goal of this project is to research and develop testing guidelines that can be used in field to assist in function and performance testing for multi-vendor equipment and systems based on the IEC 61850 standard. The objectives of the project include the following:

- Work with utilities to identify key IEC 61850 testing issues in critical processes, including acceptance tests and field and maintenance tests within substation environment. Perform R&D on key requirements and create use cases based on the most recent release of the standard (edition 2 or later).
- Develop guidelines, good practices, and testing tools to support field deployment of the IEC 61850 standard.
- Develop an IEC 61850 testbed system in EPRI laboratories to demonstrate the developed methodologies and approaches, and use it as a vehicle for a technology transfer workshop.

Project Approach and Summary

This proposed research will apply the following approaches:

- Collaborate extensively with the utilities, standard organizations, equipment vendors, and subject matter experts to address the challenges
- Develop testing guidelines and demonstrate testing concepts and methods by using the state-of-the-art multi-vendor digital relays and communication facilities in EPRI smart grid substation laboratories
- Document the good practices and field experiences by working closely with member utilities

Benefits

This project can provide substantial new learning in application and deployment of the IEC 61850 standard for next-generation substation development. This work will be in support of NIST SGIP (Smart Grid Interoperability Panel) testing and conformance committee activities and contribute to the maturity of the IEC 61850 standard. The work will benefit the public in that it provides an important step in achieving the smart grid specified in the 2007 Energy Independence and Security Act. This act clearly described the benefits to society of a smart grid and the application of interoperability standards, such as IEC 61850, which is a key aspect of migrating today’s power system infrastructure to a smart grid.
Geomagnetic Disturbance (071802)

Background, Objectives, and New Learnings

Geomagnetic disturbance (GMD) is not a new phenomenon, yet it is of rising concern to the North American electric power sector due to increasing awareness, grid complexity, and societal dependence on reliable electricity supply. GMD has the potential to cause system disturbances and equipment damage. In an extreme case, GMD may have the potential to cause widespread electric disruption and destroy critical infrastructure. The industry has not yet developed a clear understanding of the possible magnitude of solar storms and their impact on the electrical system.

For the purposes of this project, an extreme event is characterized as being ten times (10X) the magnitude of the solar storm that led to the collapse of the Hydro Quebec system in the early hours of March 13, 1989.

Some scientists estimate that such an extreme event may result in a system collapse, hundreds of large autotransformers damaged or destroyed, and an outage that will last for months rather than days. Other scientists anticipate that existing system protection schemes will adequately protect the system and by disconnecting selected transmission equipment they could end up with little or no equipment damage, and that after the storm, the system could be quickly restored.

The industry needs to have a clear understanding of the possible severity and probability of damages to develop mitigation solutions that are adequate for these scenarios based on fact-based analysis. Specifically, this project’s objective includes the following:

- Determine the likely impact of an extreme event, as defined above, on the North American electrical system utilizing present system protection capability and practices
- Identify technologies available today, or in the near term, to mitigate equipment damage, reduce the extent of the interruption, and speed recovery
- Identify technologies that can be developed to reduce the impact of the storm as well as lower the cost of protection

Project Approach and Summary

The initial objective will be to determine the state of knowledge of GMD. This will include a review of the available literature and interviews of industry experts to collect and validate industry data on the probability of extreme events and the extent to which storms can reasonably be anticipated.

System models will be developed of representative regions of the North American grid in cooperation with North American Electric Reliability Corporation (NERC) staff. The models are designed to determine how the system and equipment respond to various storm scenarios or to evaluate candidate mitigation technologies. All results will be analyzed by a technical team comprised of NERC, utility, and EPRI staff.

Today, numerous technologies and approaches are available with the claim to lessen the impact of solar storms. A center of expertise will be developed to test and assess mitigation technologies, perform system studies, and answer member questions and concerns.

Existing technologies will be tested, such as neutral blockers and operational strategies. Mitigation will include technologies that can reduce the extent of the impact or reduce the duration of outages. The impact on the protected equipment will be evaluated, along with the possible impact on adjacent lines, transformers, and mitigation equipment.

A guidebook covering mitigation and recovery practices will be produced covering present and emerging technologies for forecasting, practices covering early warning, operations, and restoration, as well as mitigation technologies.
Benefits

The understanding developed in this project may help utilities in preparing for the rare events of massive solar storms and operate the grid through such events and minimize the risks of equipment damage or prepare for fast recovery from widespread outages and equipment damages.

In addition, it may identify gaps in forecasting and mitigation solutions and give guidance on the economic feasibility of available mitigation technologies.
Sunburst Network For Geomagnetic Current (003679)

Background, Objectives, and New Learnings

The Electric Power Research Institute’s (EPRI) SUNBURST network is both an organized method for measuring geomagnetically induced currents (GICs) and their effects, and a source of data for continuing research studying the cause, effects and mitigation of GIC impacts on electrical power systems. While the primary focus is operating the monitoring network, the data collected in this project will be used for feedback into new prediction models that will serve as advance warnings, that is, the NASA Solar Shield project. The SUNBURST project also supports an annual event where relevant scientists from the field of solar phenomena/space weather come together to discuss common issues and concerns related to GICs.

The SUNBURST network consists of a consortium of member utilities where near-real-time continuous monitoring of large power transformers is performed to assess the impact of impinging solar storms on the grid. By measuring these GICs along with current and voltage harmonics—the SUNBURST system communicates the breadth, intensity, and localized transformer saturation impact as these storms occur.

Solar storms can be described as magnetic field lines looping out of and into the sun. Often associated with these disturbances are discharges of tremendous amounts of super heated matter, called coronal mass ejections, consisting of mostly ionized hydrogen and helium. When these subatomic particles reach earth, their interaction with the earth’s magnetosphere has the potential to afflict electric power systems resulting in everything from minor upsets to major outages.

The full solar cycle consists of two half-periods of 11 years each, marked by reversals of the sun’s polarity. During one half-cycle, solar disturbances are in alignment with the earth’s magnetic field; in the other, they are antiparallel. Peaks in these disturbances occur midway through the half-cycles and are sometimes more severe during the odd-numbered 11 year periods. The next cycle of solar activity peaks around 2013.

EPRI has supported research in this area for a number of years. EPRI organized a conference on the subject in 1989 (collected as EPRI Proceedings TR-100450). Based on encouragement that came out of the conference, EPRI funded a basic study of how a reporting network might be set up and what quantities it might usefully measure (summarized in EPRI report TR-104167).

Over the last decade, EPRI has accumulated a body of data and experience about correlations between space and earth conditions associated with problems on the grid. In addition, EPRI has measured geomagnetically induced currents and their effects and created a user organization to study the causes, effects, and mitigation of GIC impacts on electric power systems.

Project Approach and Summary

Participation in this project will support new prediction models that can serve as advance warning for the effects of solar activity on the North American power grid. At the same time utilities will receive processed results from existing monitors during actual events. New participants will have an option to deploy their own monitor(s) adding to these research data.

Benefits

This activity generates substantial new learning on how Geomagnetically Induced Currents progress during a solar storm – and how this data relates to prior observations from Satellites or solar observations. The results from all Sunburst sites will help improve the prediction tools. There is significant public benefit derived from the new learning and data gathered. The public benefit is that through a deeper understanding of Space Weather impacts in the electric grid, steps can be taken to mitigate these effects. The resulting benefits would be in improved reliability of the supply of electricity.
Substation Seismic Studies (049551)

Background, Objectives, and New Learnings

IEEE Standard 693, Recommended Practice for Seismic Design of Substations is used by electric power utilities to qualify substation equipment for seismic movements. Deficiencies exist in the present standard and information is unavailable for dynamic response that may be used to better analyze equipment, and permit their evaluation in case of limited configuration changes, such as insulator substitution. Representatives from utilities who had participated in the IEEE 693 Working Group as well as several other utilities were contacted for participating in a collaborative project to address deficiencies in the standard and most had expressed interest.

A representative from each participating utility forms the governing body (under the direction of EPRI) for the project. Testing would be performed at appropriate test facilities as directed by EPRI, with input from the participants. The project is managed by an EPRI manager. Technical services are provided by the EPRI Technical Manager. The project addresses the deficiencies exist in the present standard, especially those related to details left unspecified, by performing tests in the laboratory. These tests are intended to gather dynamic response information that may be used to better analyze the equipment, and permit their evaluation in case of limited configuration changes, such as insulator substitution. Equipment qualified using the recommended practice thus will perform acceptably under reasonably anticipated strong ground motion.

The knowledge gained from this project is intended to seismically qualify substation equipment using IEEE Standard 693, IEEE Recommended Practice for Seismic Design of Substations. An important part of the project is to determine what deficiencies exist in the present standard, especially those related to details left unspecified. Tests are to be performed by a laboratory to gather dynamic response information that may be used to better analyze the equipment, and permit their evaluation in case of limited configuration changes, such as insulator substitution. As stated in IEEE 693, equipment qualified using the recommended practice should "perform acceptably under reasonably anticipated strong ground motion."

Project Approach and Summary

The following approach is adopted.

EPRI will select the item(s) of equipment that is (are) to be tested for each year. EPRI establishes equipment support structure specifications and vibration test requirements, electrical equipment specifications, and test specifications. EPRI will select a vibration testing facility (and electrical testing laboratory, if required) to perform tests and EPRI draws a contract for laboratory services.

The EPRI Technical Manager prepares a Request for Proposal and issues it to equipment manufacturers. Equipment manufacturer(s) will then be selected to participate in the project. The Technical Manager prepares a test plan in conjunction with the testing laboratory and the equipment manufacturer. The testing laboratory performs qualification tests of one or more item of equipment under the overview of the Technical Manager. The manufacturer and the testing laboratory prepare qualification documentation for the equipment that is qualified following IEEE 693 requirements. The Technical Manager prepares a project report describing the project. The test procedure described below will be followed.

Test Procedure

Governing Standard: EPRI intends to conduct testing under the governing standard, IEEE 693-2005, with modifications that are deemed appropriate. In general, the input motions, instrumentation, test sequences, functional tests, and other requirements specified by the referenced standard will be used. Improvements recently recommended for inclusion in the standard will be used in this project to the extent possible.

Test Sequence: Each item of equipment is expected to undergo tests required by IEEE 693-2005, with modifications as determined by the EPRI Technical Manager, with input from the participants. It will first be qualified at the Moderate Required Response Spectrum (RRS) level, then the High RRS level. If lower level tests are completed, and there is reasonable assurance that higher level tests can be achieved, tests up to the High Performance Level (PL) of IEEE 693 will be performed. Failure of a test article beyond the RRS level(s) will
not be deemed as a failure of a qualification test, provided that the test article met all qualification requirements at the lower level.

Benefits

The project addresses deficiencies in the existing standard that evaluates performance of substation equipment, to ensure that qualified products will have higher probability of surviving earthquakes. As a result, both repairs of damaged equipment and power interruptions will be reduced, thus enhancing continuity of power supply to the public and lowering operating costs of electric power utilities.
Computer Based Training Videos for Circuit Breakers (072020)

Background, Objectives, and New Learnings

While requirements for service reliability have increased, utilities also are pressed to control costs while maximizing performance from existing—and often aging—assets. Today’s performance-driven companies must obtain maximum value from their assets while optimizing the use of shrinking technical staff and financial resources. Effective equipment maintenance is essential for best-practice asset management. However, often in-house maintenance and testing procedures are inconsistently applied, outdated, or even nonexistent and experienced craftspeople are less available.

High-voltage circuit breakers are not only essential to the protection of other system components under fault conditions, their reliable switching operation also is necessary for maintaining optimum system conditions. A breaker’s failure to operate as required can result in equipment damage, increased system disturbance, and loss of load.

The installed base of high-voltage circuit breakers is dominated by aging technologies. Circuit breaker maintenance—key to reliable operation—accounts for a major portion of a utility’s substation maintenance budget. Training maintenance staff, however, has become increasingly challenging. New personnel or those re-assigned to different job functions, face a steep learning curve in managing or implementing substation equipment maintenance. Much valuable information resides with experienced workers, where it is subject to loss upon their departure. Substantial portions of utility in-service breaker designs use older technologies no longer supported by manufacturers and opportunities for on-the-job training have declined.

Advanced video-based training may help utilities maintain their breakers reliability despite leaner budgets and less experienced personnel. The objective of this project is to develop computer-based video training modules to improve the proficiency of personnel maintaining high-voltage circuit breakers.

Video-assisted training offers a cost-effective approach to increase the proficiency of substation maintenance staff and help ensure that aging circuit breakers will continue to operate reliably. Video can add value through new learning in training and job preparation in several ways:

- Show key actions to dramatically enhance and clarify printed maintenance procedures and training manuals
- Document the knowledge of experts before they retire
- Demonstrate complex breaker maintenance tasks including disassembly, assembly, and test
- Explain the general rules and basic reasons behind specific maintenance tasks and tests
- Use real-world examples to illustrate failure modes and degradation mechanisms
- Provide easily available material to refresh lessons learned before undertaking maintenance tasks

Project Approach and Summary

The project team will develop computer-based circuit breaker maintenance training videos to meet the specific needs of participating utilities. Videos may be of two general types:

- Complete procedure videos on either generic breaker types (for example, oil or gas), or on specific breaker models of interest
- Targeted videos of specific maintenance tasks or parts of a maintenance procedure (for example, installing a bearing or disassembling the mechanism in the cabinet)
The project team’s focus is on older circuit breaker designs that no longer have manufacturer support. Project scope will be tailored to individual utility needs and may include:

- Development of application-specific procedures that would provide a foundation for video training
- Animation of difficult to observe breaker movements and maintenance actions
- Video documentation of experienced, on-the-job utility crews
- Development of training video production and content requirements for use by utilities to specify production by breaker suppliers or by other parties

**Benefits**

- Capture technical expertise
- Increase proficiency of maintenance staff
- Improve effectiveness of maintenance training
- Extend circuit breaker life
- Increase circuit breaker reliability
Transformer & Circuit Breaker – Fleet Management (072021)

Background, Objectives, and New Learnings

Because of the adverse demographic distributions common in many utilities, existing methods need improvement to provide effective management of the fleets of aging transformers and high-voltage circuit breakers. Operating substation transformers and high-voltage circuit breakers reliably and with a low risk of failure at or beyond typically assumed design lives is a subject of interest for many utilities. Consequently, developing and justifying a repair/refurbish/replace management strategy for such populations, and the rational basis for it, are increasingly important.

Fleet management requires the tools and methodologies to better assess equipment performance and risk and provide quantitative information to drive asset management decision processes. In addition, fleet management risk and performance assessment tools can be integrated into smart grid implementations, turning smart grid-generated equipment status data into information and providing timely equipment and system condition and risk exposure metrics to improve operating reliability and efficiency. For practical implementation, fleet management tools should be based on actual equipment condition and rely on readily available data. EPRI has developed a foundation for a suite of integrated risk and performance assessment tools for substation equipment and successfully demonstrated the concepts in the application of algorithms at a number of utilities. However, there are still significant gaps in the algorithms, which when addressed, is expected to produce significant new knowledge about fleet management effectiveness.

The objective is a set of integrated substation equipment risk and performance assessment tools designed to provide the information required to better assess equipment performance and risk and provide the quantitative information needed for best-practice fleet management and efficient operation.

Project Approach and Summary

Building on an established framework, the objectives of this project are to address primary concerns, issues, and utility needs for managing aged substation transformer and high-voltage circuit breaker fleets by assessing data availability and quality and its potential for short- and longer-term application to fleet management, to formulate and assess applicability of innovative methodologies for fleet management applications, to further develop and apply the new methodologies to quantitative business case analyses for a range of specific host utility fleet management strategies, to populate and exercise models with utility data, and to carry out sensitivity analysis for business cases being considered.

Benefits

Project results will help asset managers and maintenance personnel deal with the problem of populations of aged transformers and circuit breakers by formulating innovative, risk-based analytical methodologies to address emergent issues, maintenance strategies, monitoring strategies, and longer-range investment strategies. Specific benefits include the following:

- Reduce overall maintenance costs, project capital cash flow, minimize unplanned expenses, and maximize the benefit and value of planned work
- Improve reliability and availability via reduced reliance on time-based maintenance by using asset health and condition analysis to determine maintenance actions
- Enable more effective use of existing infrastructure and data and efficient use of maintenance personnel to manage operational risk
Improved Bushing Current Transformer Models (072022)

Background, Objectives, and New Learnings

Current transformers (CTs) are ubiquitous in substations. They are components of circuits, as are lines and transformers, and they too have ratings associated with their operation. In some cases, they are the lowest-rated component in a circuit, and, therefore, limit the entire circuit's rating, particularly for emergency operations. While much work has been done on increasing, improving, or optimizing the ratings of lines, transformers, cables, and other CT components, CT ratings have been virtually ignored. The ratings used by power companies for CTs are typically the nameplate ratings, and these are generally unnecessarily conservative, especially during high-load contingency situations. Some power companies and equipment providers will define a "Rating Factor", which is the amount above (or below) the nameplate rating that a CT can be confidentially operated with continually, or for limited periods. But these ratings factors are not always known, and power companies must assume a value of 1.0, thereby restricting the CT rating to its nameplate rating, even during emergencies. The thermal ratings and rating factors of older units are particularly not well characterized. In this project, EPRI will perform theoretical and experimental studies to better define the rating factors of CTs for continuous and emergency operation.

Project Approach and Summary

EPRI will purchase samples of new CTs and obtain aged samples donated by interested members for study. Heat run tests will be performed, some to the point of failure. The tests will involve instrumenting samples with thermocouples and running them at ranges of current levels and time periods in order to assess their rating factors under various operating conditions. A methodology for defining rating factors for classes of CTs will be developed. An aging model for CTs also will be assessed.

Benefits

The results will provide a scientific means for power companies to better understand the operating characteristics of the current transformer and provide the basis to operate the CTs and circuits safely. They may give utilities the decision support to keep the existing instrumentation in place, or target replacement programs for groups of CTs to maintain reliability when operating the system with high operating current while keeping cost low.
Aging T&D Infrastructure - Environmental Risk Management (067694)

Background, Objectives, and New Learnings
As the infrastructure for the transmission and distribution of electricity grows older, risks to human health and the environment from leaks and spills of fuels, dielectric fluids, and other liquids may increase, resulting in increased financial risk to power companies. The utility industry needs to understand risks and vulnerabilities from aging infrastructure, and it needs approaches to identifying and assessing those risks and vulnerabilities, as well as to prioritizing actions to mitigate those risks. This project will help companies to proactively assess risk to allow prioritization of resources for repair and replacement before incidents occur.

The project addresses this question: how can a utility estimate, analyze, and prioritize its risk from aging infrastructure? The project is developing a Relative Risk Model for assessing aging electrical equipment that will integrate information on components, potential for releases, migration of released materials, environmental settings, toxicology, environmental fate and effects, and financial implications. The model can facilitate evaluation of release scenarios with the highest potential for environmental and health impacts. The utility conducting the analysis can benefit by being able to proactively address its greatest risks, conducting repair and replacement activities before spills, explosions, and other incidents take place. The public can benefit from increased reliability of the electric system (fewer interruptions) and from decreased impacts to human health and the environment (fewer incidents).

Project Approach and Summary
EPRI is developing a conceptual Relative Risk Model and is populating it with available data on components, potential for releases, migration of released materials, environmental settings, toxicology, environmental fate and effects, and financial implications. Through case study applications with individual companies, EPRI will improve and test the model. Participating companies will gain the results of the case study assessments, which they can use to move forward with repair and replacement of vulnerable equipment.

The Relative Risk Model is being developed with base funding. Detailed case studies will be conducted with individual companies with supplemental funding. The generic results of the case studies will be incorporated into the model but not linked to any company. Program funders will be entitled to receive the model and a case study summary. Each supplemental funder will receive a detailed report on its case study, as well as the model and a case study summary.

Benefits
Benefits of assessing risks include improved decision making, cost avoidance for contamination and resulting impact that do not occur, cost reduction for remediation that is limited in scope, and substantial public benefit from protection of human health and the environment.
**ELF Personal Monitor (070520)**

**Background, Objectives, and New Learnings**

The use of implanted medical devices that address a wide range of health conditions is rapidly expanding (see EPRI Technical Update, "Electromagnetic Interference with Implanted Medical Devices: An Update," Product # 1016815). Although these devices are designed to withstand interference from external electric and magnetic fields, various studies have indicated that the probability that interference can occur cannot be assumed to be zero. A comprehensive workplace safety program would benefit from the availability of a personal monitor that informed a worker with an implanted medical device (such as a cardiac pacemaker or defibrillator) that the electric and/or magnetic field in his or her ambient environment was approaching levels that could conceivably interfere with the implant's performance.

**Project Approach and Summary**

The aim of this research is to develop a working prototype of a personal electric and magnetic field exposure meter, with accompanying software and documentation, designed to provide alerts in the presence of high electric or magnetic fields. The monitor will be designed to be easily worn by a person (small, compact, and lightweight) and to be capable of continuously monitoring electric and magnetic field levels within typical electric utility and industrial environments. The monitor could be readily programmed by a company representative for various electric and magnetic field thresholds (for example, by percentages of a known EMF guideline such as that from the American Conference of Governmental Industrial Hygienists) and could alert the wearer in environments where those thresholds are exceeded. The unit will build on the existing features of the EMDEX PAL, which was used successfully and safely in monitoring magnetic field exposures across the United States in the U.S. Research and Public Information Dissemination (RAPID) Program's "1,000-Person Study." The unit will be adapted to detect electric and magnetic fields up to levels relevant to potential device interference.

**Benefits**

Cardiac pacemakers and defibrillators are probably the most widely used implanted medical devices, allowing many men and women to return to productive working lives. It is essential that these individuals be provided with an appropriate tool that, when combined with any of a number of other possible measures (such as worker training and appropriate signage), would help minimize the probability of an interference event.
HVDC Transmission - Program 162

Program Overview

Program Description

The electric power industry is faced with difficulties in acquiring right-of-ways, integrating renewable power sources into an ac power system, and it is under pressure to improve the reliability of the power grid. High-voltage direct current (HVDC) offers many advantages to meet these challenges. By converting an ac line to dc, an electric utility is able to raise the power transfer capability of an existing transmission corridor. HVDC technology is a solution for the integration of renewable power sources such as wind and solar energy into an ac power system. HVDC links could be installed by a utility to isolate its power system from neighboring utilities. HVDC technology also has been identified as a key component for the future smart grid.

Flexible ac transmission system (FACTS) technology offers an alternative to dc. FACTS can be used to control power flow. An ac cable with a FACTS controller could be a competitive solution to a dc cable for integrating renewable power sources. Both HVDC converters and FACTS also share some common technologies. Therefore, a FACTS supplemental project is included in this HVDC program to provide an alternative option to the industry.

Research Value

Applications of HVDC technology are evolving beyond its traditional role of bulk power transfer. The electric power industry has to understand different applications of the technology well in order to take full advantage of it. The program provides the following:

- Technology awareness through technology watch newsletters, conferences, and workshops
- Experience of recent HVDC technologies, integration of HVDC into an ac system, HVDC electrical effects, system and component performance to members who are considering adopting HVDC for either bulk power transfer, power system performance improvement, and integration of renewable power sources or transmission system flow management
- Options to increase the capability of existing transmission corridors by providing methods to convert HVAC lines to HVDC lines, to construct hybrid ac and dc lines, and to enhance power flow management using HVDC or FACTS

The program offers comprehensive information for both owners and non-owners of HVDC systems.

Approach

Electric Power Research Institute (EPRI) research in HVDC yields a variety of data and information that may be beneficial to program members. This information will come in a number of forms and is expected to include the following:

- Evaluating and testing HVDC components and system performance
- Studying HVDC electrical effects such as corona, audible noise, electromagnetic interference, in both radio and TV frequencies, as well as electric fields and ions so that companies can better understand how dc lines may affect their environment
- Developing strategies and guidelines for converting ac lines to dc lines to increase and manage transfer capability on existing transmission corridors
- Evaluating voltage source converter (VSC)-based dc transmission and advanced power electronic devices for adoption and identifying research and Development (R&D) needs to further enhance the use of these technologies at higher voltages
- Providing leadership in theoretical and experimental fronts in HVDC, ac-to-dc line conversion, hybrid ac and dc, and the operation of HVDC systems
• Demonstrating HVDC technology options at utility sites
• Providing HVDC technology awareness by publishing reports and organizing industry-wide conferences and workshops
• Publishing the HVDC reference guides for the design and operation of HVDC systems
• Resolving operational concerns of owners and operators of existing HVDC systems and those considering the addition of HVDC to their systems

Accomplishments
In the past, the HVDC Systems program has delivered valuable information that has helped its members and the industry in numerous ways. Some examples include the following:

• **Life Extension Guidelines for HVDC Converter Stations and Transmission Lines**: Extends life spans of individual equipment components, thus improving individual equipment reliability through best-practice operation and maintenance strategies. Enables members to extend life spans of existing HVDC systems. Avoids substantial costs as a result of improved and predictable network performance through an optimized maintenance program.
• **Assessment and Evaluation of Developing HVDC Technologies**: Evaluation of voltage source converter (VSC)-based dc transmission and advanced power electronics and identification of technical barriers that need to be resolved to push the technologies to higher voltages.
• **HVDC Reference Book**: Provides state-of-the-art information for planners, designers, and operators.
• **AC-to-DC Line Conversion**: Assesses the reliability impact when introducing HVDC links to existing transmission systems by converting selected ac lines to dc. Such conversions may increase power transfers on corridors by as much as 50% to 70%.
• **Testing**: Provides information from HVDC equipment and component testing at the EPRI Lenox laboratory.

Current Year Activities

• Provide a technology watch newsletter with the latest developments in HVDC technologies
• Update the leading reference guide for the design and operation of HVDC systems
• Resolve operational concerns of owners and operators of existing HVDC systems and those considering the addition of HVDC to their systems
• Evaluate the impact of integrating HVDC into an ac system
• Evaluate HVDC system performance and conduct component testing
• Evaluate HVDC electrical effects such as electromagnetic interference, fields, and corona in laboratory test settings
• Arrange a demonstration of AC-to-DC line conversion at a utility site

Estimated 2012 Program Funding

$1.4M

Program Manager

John Chan, 650-855-2452, jchan@epri.com
Summary of Projects

PS162A HVDC Technology Assessment and Evaluation (069266)

Project Set Description

This project set offers technical information to electric power utilities on HVDC systems. The information covers both new technologies and experience gained in the past 50 years from operating HVDC systems. New applications of HVDC technology are reviewed, investigated, and examined. The impact of a new HVDC system on the existing acsystem is studied. This project set is suitable for members who are interested to improve their knowledge on HVDC for traditional and new applications. It will help members in the selection of proper HVDC technologies for their applications. Knowledge transfer will be in the form of technology watch newsletters, reference books, workshops, conferences, and studies.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>P162.003</td>
<td>HVDC Technology Surveillance and Reference Guidelines</td>
<td>This project will periodically publish a newsletter with the latest information on current and new HVDC developments and installations, as well as update the HVDC Reference Book. In addition, an HVDC conference or HVDC workshop will be organized every year to disseminate technical information on latest HVDC technologies.</td>
</tr>
<tr>
<td>P162.004</td>
<td>Applications of HVDC Technology and New Developments</td>
<td>This project will address various HVDC applications. One of the applications is connecting renewables to the main grid. It also will provide different transmission interconnection options based on technical and economic benefits. Further, it will explore and address issues related to designing and operating DC grids and DC circuit breakers.</td>
</tr>
<tr>
<td>P162.009</td>
<td>Integrating HVDC in an AC Grid</td>
<td>This project addresses various system impacts when HVDC interconnections are implemented in a meshed AC grid. Overall transmission capacity can be increased by adding HVDC interconnections with a much greater flexibility in controllability and increased reliability.</td>
</tr>
</tbody>
</table>

P162.003 HVDC Technology Surveillance and Reference Guidelines (062104)

Key Research Question

It is important that the power industry has access to the latest developments and advances in HVDC technology. EPRI continues to build a comprehensive library of information on HVDC technology for the benefit of the industry. EPRI has been developing reference materials that capture and consolidate related HVDC information and knowledge.

Approach

This project seeks to enhance the knowledge of HVDC technology in these ways:

Publish HVDC Technology Watch newsletters: To foster future developments in the HVDC area, as well as to disseminate technical developments in a timely manner, a newsletter will be published periodically with the latest information on current and new HVDC installations taking place worldwide. The HVDC Technology Watch tracks developments in HVDC technologies such as the following:

- VSC dc transmission for both overhead and underground
- Application of dc for integrating renewables and other new power sources
- Segmentation of ac systems with dc ties
- New cables for dc operation.

**Organize HVDC Conference or Workshop:** An HVDC conference or workshop will be organized every year to facilitate technical information exchange, and it will be sponsored by EPRI and utility members.

**Update the HVDC Reference Book:** Information will be developed for the *HVDC Reference Book* (also known as the *Olive Book*). Research will help capture the latest information on HVDC technology and operational data for existing HVDC systems. A formal peer review of the existing EPRI HVDC handbooks and related reference books led to recommendations for critical reference book revisions. The handbook will provide the following:

- Guide members in specifying an HVDC system by leading them through each step of the design process and confirming that the implications of tradeoffs are well understood. The book will cover the design of the line, converter, and associated converter substations.
- Guide members in considering the environmental aspects of these systems, since they differ between HVDC systems and ac systems. This handbook will study these aspects and provide members with insights into the interactions between HVDC systems and the broader society.
- Guide members in assessing existing HVDC systems and the options available when addressing repair or replace decisions and life extension options.
- Provide tools to help optimize HVDC system design.

In December 2010, an *Interim HVDC Reference Book* (1022330) with 12 chapters was published. The remaining chapters will be updated in 2011 and 2012. An electronic version of the *Reference Book* with all 24 chapters will be published by the end of 2012. Additional chapters on new topics such as life extension, ac-to-dc conversion, grounding, and other relevant subjects for HVDC will be added to the *Reference Book* in 2013 and beyond. An updated version of the *Reference Book* in electronic form will be available the end of each year. Pending on the demand, a hardcopy version may be published. A tutorial—power point presentation with course notes—will be developed in 2014 and onward, which can be used to train utility engineers in a self-study mode or in a classroom setting. Industry workshops based on the tutorial will be provided in future years.

The technology watch, conference, and reference book provide valuable insights into HVDC technologies for companies presently operating HVDC systems and those contemplating HVDC as a possible transmission option.

**Impact**

- Increase understanding based on technical information about HVDC technology options
- Enhance dc power system reliability and availability through performance and maintenance improvement strategies
- Enable companies to reduce transmission costs by fostering construction and maintenance of cost-effective HVDC infrastructures to increase power transfer levels
- Provide a comprehensive resource for members to remain abreast of HVDC technology and ensure that engineers have the most current information

**How to Apply Results**

State-of-the-art information about HVDC technology from the most current *EPRl HVDC Reference Book* will help managers, planners, and engineers simplify cost-effective operation, maintenance, and planning decisions in the HVDC area. The technology watch newsletter and the annual HVDC conference or workshop will help members facilitate technology transfer and the generation of future research ideas.
## 2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>HVDC Tech Watch - Newsletter:</strong> This HVDC Technology Watch newsletter will document the latest information on existing and newly planned HVDC installations around the world. In addition, it will highlight the latest technology breakthroughs in this area.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>HVDC Reference Book (Olive Book):</strong> The remaining chapters of the HVDC Reference Book (Olive Book) will be updated in 2012. An electronic version of the Reference Book with all 24 chapters will be published.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>HVDC Workshop:</strong> An HVDC workshop will be organized along with the HVDC Task Force Meeting to provide technical information on the latest HVDC topics.</td>
<td>12/31/12</td>
<td>Workshop, Training, or Conference</td>
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## Future Year Products

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<td>12/31/13</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>HVDC Conference:</strong> An HVDC conference will be organized along with the HVDC Task Force Meeting to share the latest technical information among utilities, vendors, universities, and research organizations.</td>
<td>12/31/13</td>
<td>Workshop, Training, or Conference</td>
</tr>
<tr>
<td><strong>HVDC Reference Book (Olive Book): Additional New Topics:</strong> Additional chapters on new topics such as life extension, ac-to-dc conversion, grounding, and other relevant subjects for HVDC will be added to the Reference Book in 2013 and beyond. An updated version of the Reference Book in electronic form will be available the end of each year.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>HVDC Tech Watch - Newsletter:</strong> This HVDC Technology Watch newsletter will document the latest information on existing and newly planned HVDC installations around the world. In addition, it will highlight the latest technology breakthroughs in this area.</td>
<td>12/31/14</td>
<td>Technical Resource</td>
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<tr>
<td><strong>HVDC Reference Book (Olive Book): Tutorial:</strong> A tutorial—power point presentation with course notes—will be developed for some chapters of the HVDC Reference Book, which could be used for training in the classroom setting or in a self-study mode.</td>
<td>12/31/14</td>
<td>Technical Update</td>
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<td><strong>HVDC Workshop:</strong> An HVDC workshop will be organized along with the HVDC Task Force Meeting to provide technical information on the latest HVDC topics.</td>
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### P162.004 Applications of HVDC Technology and New Developments (063311)

#### Key Research Question

The electric power industry has to understand different applications of HVDC well in order to take full advantage of the technology. Applications of HVDC technology are evolving beyond its traditional role of bulk power transfer. By converting an AC line to DC, the power transfer capacity of an overhead line could be increased by 50 to 100%. In certain cases, DC cables may be more compatible with renewable power sources than an AC cable. VSC converter technology is improving and its capacity increasing. Advancements in this technology may
open up new applications. All these new developments have to be assessed and evaluated for suitable adoptions. Guidelines are needed in selecting the right application and in selecting between an AC and a DC system.

This project investigates the applications of HVDC technology for conventional power sources and for new sources such as wind and solar and to develop concepts such as AC-to-DC line conversion, DC grids and DC circuit breakers.

**Approach**

In previous years, an in-depth study was conducted on AC line conversion to DC operation and a consolidated report "AC to DC Power Transmission Line Conversion " was published in 2010 (Product ID 1020114). An arrangement is being pursued to demonstrate the AC-to-DC conversion concept in a utility.

In 2012, the suitability of DC cables for renewable power sources will be studied. Challenges of cable technology for DC operation and issues related to operating a DC cable, especially at high DC voltages will be investigated. The advantages and disadvantages, both technical and economic, of connecting renewable power sources using a DC cable system will be compared with an AC cable system. Factors that influence the selection of a DC cable will be determined. A tool including methodology and software to assist utility engineers to make AC versus DC decisions will be developed.

In the following years, the tasks below are considered. The order of carrying out these tasks will be prioritized by members.

- Study the technical requirements for a convertible AC cable for future DC operation, and vice versa.
- Perform technical and economic studies of various types of DC technologies and develop guidelines for applications.
- Compare different AC and DC options to meet system expansion requirements.
- Investigate DC grid concepts for distributed renewable generations including the requirements for DC circuit breakers.
- Demonstrate new DC concepts developed by manufacturers such as the multiple-level VSC converters. In this case, the concept will be studied systematically to determine the optimal number of levels that are needed to achieve the required power without any AC side filter. New DC concepts that are developed by either the manufacturers or universities may also be field demonstrated.

**Impact**

High-voltage direct current lines and cables may have a large impact on the reliability and economic performance of an existing power system. This project strives to provide information, engineering approaches, and decision-making support to help companies integrate renewables and other applications using HVDC technology, which may help an owner accomplish the following:

- Reduce the costs of power transmission, potentially reducing electricity rates to end-use customers
- Increase overall system controllability, stability, and reliability
- Make informed decisions based on technical and economic aspects of different technologies
- Assist implementing new concepts such as dc grids and dc circuit breakers

**How to Apply Results**

This project helps planners and engineers in selecting a transmission systems for interconnecting renewable generation sources. The project provides multiple technological and economic options including HVDC lines or cables and HVAC lines or cables and provides benefit-cost comparisons for different options. In addition, this project will provide methods of designing and operating dc grids and dc circuit breakers.
2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>DC Cable Technology Assessment &amp; Comparison of DC cable versus AC Cable: State-of-the Science: Review cable technology for HVDC operation and investigate issues related to operating a cable for HVAC and HVDC operation. Provide comparisons between DC cable and AC cable with reactive power support for interconnecting renewables.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Tool for Selecting AC versus DC: Develop methodology and a software tool with typical cost data to assist utility engineers for making AC versus DC decisions.</td>
<td>12/31/12</td>
<td>Software</td>
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Future Year Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Comparison of Different Options for System Expansion Requirements: Provide comparison of different options such as dynamic ratings, voltage upgrade, ac-to-dc conversion, advanced conductors, and superconducting cable for system expansion.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Improved Tool for Selecting AC versus DC: Improve the software tool based on utility input and provide the improved tool to assist utility engineers in making AC versus DC decisions.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td>Technical and Economic Guidelines for DC Applications: Perform technical and economic studies for DC applications and develop guidelines.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Design and Operational Challenges of DC Grids and Requirements for DC Circuit Breakers: Document design and operational issues of DC grids and evaluate the requirements for DC circuit breakers.</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Technical and Economic Guidelines for DC Applications: Perform technical and economic studies for DC applications and develop guidelines.</td>
<td>12/31/14</td>
<td>Technical Report</td>
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</table>

P162.009 Integrating HVDC in an AC Grid (072082)

Key Research Question

The use of HVDC interconnections between regions of an AC grid is being considered to an increasing extent because of the growing challenge of power system development. For technical and economic reasons, HVDC may be considered if a long overhead line or cable connection is necessary, or because the conversion of an existing AC line to HVDC operation can achieve increased transfer capacity. Difficulties with building new overhead lines may lead towards considering underground HVDC connections inside AC grids operating in parallel with AC lines or converting AC lines for DC operation. In addition, with the growth of on-shore and off-shore wind generation, HVDC lines and submarine cables are often the most suitable options, particularly for long distances.

Applications of HVDC technologies to the existing power grid are thus inevitable. HVDC connections perform differently to AC connections during steady-state, dynamic, and transient conditions. These differences must be studied. In addition, the coordination between HVDC links and AC lines in parallel should be studied for the most effective utilization of these assets in the entire power network. This project evaluates the impacts of additions of HVDC to an existing power system.
**Approach**

System planning studies will be performed as a first step before considering HVDC interconnections in the existing AC grid to assess the impacts of HVDC. The impacts of HVDC will be evaluated by using benchmark test systems and the necessary model developments to reflect the latest converter technologies such as multi-level VSC. Additional utility-specific system studies will be conducted using supplemental funding.

Typical studies to be conducted under this project include load flow, transient stability, small signal stability, and voltage stability. Various AC-DC configurations and control strategies will be modeled. The following topics will be covered. It is anticipated that all these topics will be addressed in three years. In 2012, the topics to be covered are:

- **Power Flow Control Optimization** — Adaptive control strategies will be considered to address the wide range of system operation conditions. This task requires close coordination with HVDC manufacturers who are responsible for the design of HVDC controls.
- **Power Oscillation Damping Methods** — Alternative methods for power oscillation damping will be examined using the conventional and PMU measurements local to converter stations as well as using PMU data from remote locations such as major power plant locations and transmission inter-ties.
- **Wide Area Control Systems** — Wide area control systems methods will be developed using local HVDC controls along with the wide area master controls to improve the overall power flow in the network.

The topics below will be covered in the following years. The order of carrying out these tasks will be prioritized by members:

- **Transmission Loss Optimization** — A tool will be developed to optimize overall transmission power flows while minimizing losses for various operating and planning scenarios. This may involve developing a procedure to calculate optimum power flows using existing optimal power flow programs such as TRACE.
- **Special Protection & Control Schemes** — Special protection and control schemes will be developed to maximize transmission boundary flows using HVDC fast-ramping techniques under post fault scenarios.
- **Transmission Requirements for Wind Integration** — Trade-off analysis will be carried out for both AC and DC interconnection options and technical challenges will be documented.
- **Coordination of DC Control with AC Network Control Devices** — Existing methods will be reviewed and improvements will be suggested for devices such as phase shifting transformers, series compensation devices, shunt compensation, synchronous condensers, and generator controls.
- **Transient Stability Improvements and Fault Recovery** — Studies will be conducted and the results will be documented for several scenarios.
- **Sub-synchronous Damping Enhancement** — Sub-synchronous resonance studies will be conducted using the benchmark test systems with DC and the results will be documented.
- **HVDC Models** — HVDC models for line-commutated converters and voltage source converters may be developed for load flow, stability, and transient studies.

**Impact**

- Lower overall investment cost and, thus, lower rates to end use customers
- Higher system controllability due to dc control capability
- Increased overall system stability limits
- Increased asset utilization by increasing flows on the AC lines when DC interconnections are present
- Reduced overall system losses

**How to Apply Results**

Members use project findings and deliverables in their transmission capacity expansion efforts using HVDC interconnections to meet increased load demand, as well as to integrate new renewable resources such as wind and solar.
2012 Products

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<tbody>
<tr>
<td><strong>Advanced Control Methods for Power Flow Control Optimization:</strong> Advanced HVDC control algorithms will be developed for overall power flow optimization in an AC grid with DC interconnections.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Power Oscillation Damping Methods:</strong> Alternative power oscillation damping methods will be developed using local and remote Phasor Measurement Unit (PMU) data.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Wide Area Control Systems Methods:</strong> Wide area control systems methods will be developed using local HVDC controls along with the wide area master controls to improve the overall power flow in the network.</td>
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Future Year Products

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<tbody>
<tr>
<td><strong>HVDC Models:</strong> Develop HVDC converter (LCC and VSC) models for load flow, stability, and transient studies.</td>
<td>12/31/13</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Wide Area Control Systems:</strong> Develop wide area control system strategies using DC control and other system controls such as generator and FACTS devices.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Transmission Loss Optimization:</strong> Develop a tool to optimize overall transmission flows while minimizing transmission losses.</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Special Protection Schemes:</strong> Develop special protection and control schemes for maximizing boundary flows.</td>
<td>12/31/14</td>
<td>Technical Update</td>
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**PS162B HVDC Performance and Effects (062967)**

**Project Set Description**

This project set investigates the performance of HVDC systems and components as well as electrical effects from HVDC transmission lines. A benchmark performance index is created for the overall system and each component to identify problem areas that can be improved. Component testing is to be performed. Electrical effects will be studied under laboratory environments. Through testing and research studies, guidelines will be established for acceptable levels of component performance and electrical effects.

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<thead>
<tr>
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<tr>
<td>P162.005</td>
<td>HVDC System Performance and Component Testing</td>
<td>This project involves various approaches in dealing with the challenges facing the analysis and determination of the performance level of DC lines and components. System performance statistics may be developed based on existing HVDC schemes around the world. Different HVDC components such as insulators, conductors, towers, and earth electrodes will be evaluated through research and testing to help members make informed decisions such as repair versus replacement, or to specify a new HVDC scheme. Live line studies and testing will be undertaken to better understand the various factors which influence the safety of workers. The research provides information to members to improve the performance of existing HVDC systems and to purchase reliable components for new HVDC systems.</td>
</tr>
</tbody>
</table>
### Project Number: P162.006 Electrical Effects of HVDC

**Description**

The project will study and document electrical effects associated with HVDC transmission. The underlying physics will be studied and guidelines developed. The project will provide guidance as to where mitigation strategies may and may not be needed, and describe instrumentation for performing measurements. Full-scale and small-scale experiments for refining measurements and calculations will be made. Software that incorporates the results will be developed.

### Project Number: P162.005 HVDC System Performance and Component Testing (069268)

#### Key Research Question

Understanding HVDC system performance is critical to extending the life of an existing HVDC system or building a new HVDC system. Many of the existing HVDC schemes operating in North America and the rest of the world are over 20 years old. As these systems age, benchmarking HVDC system performance becomes important in order to propose remedial measures to optimize and improve system performance. There are plans to build several new HVDC schemes in North America and the rest of the world within the next few years. Many of the line designers have limited HVDC experience in specifying and applying components on HVDC lines.

The objective this project is to develop guidelines to members on the selection of various HVDC line components either for replacements or new installations to meet required performance levels. This project will involve research and testing in dealing with the challenges facing HVDC line performance levels.

#### Approach

This project will undertake research on and testing of HVDC components such as insulators, conductors, towers, earth electrodes and hardware in order to understand overall system performance. Components used on existing lines will need to be tested from time to time to ensure their integrity and to perform investigations if a failure occurs. Components to be used on new lines or new components to be used on lines will need to be evaluated beforehand in order to confirm compatibility and performance levels. The project will help developing component specifications for HVDC lines, as well as provide guidance on line designs. For example, accelerated aging tests for components such as insulators will be performed to better understand the effects of static electric fields on the performance of insulators in general and composite insulators specifically.

Live working under HVDC conditions is not as widely practiced as under HVAC conditions. This project will study and conduct tests to determine the best practices for HVDC live working. The live line studies in this project will be done jointly with the live line studies undertaken in Program 35. This will allow for shared resources, expertise and results.

#### Impact

The research may affect members' operations in several ways:

- System performance benchmarking can lead to better understanding of what needs to be improved and what line components should be selected, which leads to better system performance.
- The life of an HVDC system can be extended by improving system performance.
- Insulator and other line component research can result in better line performance.
- An HVDC component specification guide will assist members in specifying components properly.
- Live line studies can result in better live line maintenance practices, which leads to improved staff and public safety as well as better line performance.
How to Apply Results

The research will be structured in such a way that research results will be easy to implement into day-to-day operations using standard procedures. Training courses and seminars will be held to help disseminate information into members’ companies so they can apply these results to their own HVDC system operation and maintenance.

The HVDC component specifications developed in this project can be used by utilities to increase confidence and reduce time when specifying components. The HVDC guide will give utilities an overview of the key differences between HVDC and HVAC and the application of components.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVDC Component Testing and Studies: This task will involve determining the performance levels of components used on HVDC lines. Each year the research topic is decided by member selection. Topics which could be covered include, conductors, insulators, electrodes, etc. In 2012, insulators for HVDC lines are to be studied.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>HVDC Live Line Studies: This task will document issues related to live line work under HVDC conditions. Live Line testing will be done at the Lenox high voltage laboratory to determine the best practices required for HVDC live work.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>HVDC Overhead Transmission Guide - Outline: With input from members, the contents of the HVDC Guide will first be developed. The guide to be completed in subsequent years will cover the most recent technical information on HVDC line components including performance issues and testing data to enable members to select proper materials for their use.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

Future Year Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVDC Component and Performance - Testing and Studies: This task will involve determining the performance levels of components used on HVDC lines as well as studies on overall line performance. Each year the research topic is decided by member selection. Topics to be covered may include conductors, hardware, insulators, electrodes or live line studies etc.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>HVDC Overhead Transmission Guide - Draft: A draft of the HVDC Guide will be prepared. The guide will cover the most recent technical information on HVDC line components including performance issues and testing data to enable members to select proper materials for their use.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>HVDC Component and Performance - Testing and Studies: This task will involve determining the performance levels of components used on HVDC lines as well as studies on overall line performance. Each year the research topic is decided by member selection. Topics which could be covered include conductors, live line studies, insulators, hardware, electrodes, etc.</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
<tr>
<td>HVDC Overhead Transmission Guide: A HVDC Guide with a few topics completed in the final stage will be prepared. The guide will cover the most recent technical information on HVDC line components including performance issues and testing data to enable members to select proper materials for their use.</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
Key Research Question

High-voltage direct current (HVDC) is an established technology for long-distance bulk power transmission that is more efficient than high voltage alternating current (HVAC) transmission. As electric power companies plan for their power flow needs and/or higher levels of grid stability, HVDC or hybrid (AC-DC sharing the same corridor) lines may be the most economical and reliable solutions. However, HVDC lines have special concerns that must be addressed and accounted for during the design and operation of lines. Specifically, when HVDC lines go into corona, they can cause audible noise, electric field interference, ozone production, spark discharges, and human sensations, as do HVAC lines. But unique to HVDC lines is the ejection of electric charge into space (called “space charge”). This space charge results in the formation of charged ions and charged aerosols. These charged particles result in DC ion currents to ground and into other objects such as people, distribution lines, and other utility lines, or into other electrical devices resulting in an electromagnetic compatibility (EMC) issue.

In this project, these electrical effects will be measured, studied, characterized and quantified; mitigation measures will be explored to assist power companies in the assessment and mitigation of electrical effects from HVDC lines.

Approach

This project will build upon previous work done at EPRI and elsewhere on the subject of HVDC electrical effects associated with HVDC and hybrid corridors. Because HVDC is a relatively new technology, regulations and limits of electrical effects have not, in general, been defined. The setting of limits and regulations may become critical criteria for designing and operating HVDC lines. EPRI research will include comparing the electrical effects of HVDC and HVAC lines, and analyzing this information to make sound recommendations based on the greater experiences with HVAC.

EPRI will utilize its laboratory facilities to perform small-scale and full-scale experiments to investigate the phenomena, and to develop the underlying physics, test theories, and identify mitigation methods. At EPRI's Lenox laboratory, electrical effects from HVDC lines will be demonstrated. Participants will be able to observe, measure, and immerse themselves in the HVDC environment in order to gain firsthand experience about the effects.

All results will be documented in EPRI reports, and workshops and conferences will be held to provide the necessary technical transfer activities. Software will be developed and validated for performing calculations of HVDC and hybrid electrical effects. This software provides power companies a tool to assess and design HVDC lines.

Impact

- Enable power company personnel in obtaining guidance through reports and software.
- Assist in making the critical decision if HVDC is, or is not, a viable technology for specific applications.
- Address issues about electrical effects that are brought up in permitting or other public forums.
- Optimize the design and operation of lines regarding electrical effects.
- Position power companies in meeting regulatory requirements and public acceptance.

How to Apply Results

Transmission planners, designers, researchers, and engineers will use the results of this project to explore the electrical effects of HVDC lines in order to understand where such effects may, or may not, be an issue. The research results and software can be used to optimize the design and operation of HVDC lines from the point of view of electrical effects, and will help with meeting regulatory and public acceptance of HVDC and hybrid transmission. Results will also be used to assess options for mitigation where needed.
## 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
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<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HVDC Electrical Effects - Beta Version</strong>: The results of the project will become the basis of an EPRI software product for the calculation of HVDC electrical effects. This software will become an important tools for the design of HVDC lines. In 2012, a beta version of the software will become available for testing. This software will be integrated into TLW-Gen2 to take advantage of the features of that software package.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Electrical Effects of HVDC Transmission Lines</strong>: A technical update will be issued documenting the results of all the work performed. The document will describe the underlying physics of electrical effects, and what computation methods used and assumptions made in the software. Guidance will be provided on using the software and other tools for the design and assessment of HVDC line performance, and will outline the state of regulations regarding HVDC electrical effects.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

## Future Year Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mitigation of Electrical Effects from HVDC Transmission Lines</strong>: A report will be issued focusing on methods for mitigating the impact of HVDC electrical effects. This will cover both the need for mitigation based on regulations and/or public acceptance, and the technical details for defining and designing mitigation strategies.</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>HVDC Electrical Effects - Final Version</strong>: The results of the project will become the basis of an EPRI software product for the calculation of HVDC electrical effects. This software will become an important tools for the design of HVDC lines. In 2013, a released version of the software will become available for use.</td>
<td>12/31/13</td>
<td>Software</td>
</tr>
<tr>
<td><strong>HVDC Electrical Effects - Measurement Data</strong>: Data collected from the test lines will be analyzed and documented in a report.</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Demonstration of Mitigation Techniques</strong>: Techniques for mitigating HVDC electrical effects will be demonstrated in the laboratory. Electrical effects from a HVDC line with and without mitigation are measured and compared.</td>
<td>12/31/14</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
Supplemental Projects

HVDC Cable Interest Group (072083)

**Background, Objectives, and New Learnings**

There are considerably more HVAC underground and submarine cable installations in the world compared to HVDC, simply because the latter is relatively expensive in comparison. This price difference is mainly because of the high cost of ac/dc converters to transform ac to dc and back again, usually exceeding $100M (~€75M), depending on voltage and power. However, when cable lengths exceed the critical length for effective transmission of ac real power, dc systems become necessary. The choice of a dc power transmission cable system in preference to the more conventional ac cable option would generally be made in cases where the power transfer requirement is greater than 150–300 MW and one or more of the following characteristics apply:

- Long length (typically 25 miles [40 km]) submarine cable link or interconnection, with length limits mainly dependent on system voltage and ampacity.
- Intermediate length (typically 5 to 25 miles [8 to 40 km]) submarine cable interconnections between two large ac transmission networks where power transfer control is a potentially serious problem. A dc cable system provides an asynchronous or flexible transmission interconnection.
- Reinforcement of a long-length ac transmission system in areas of high load density (cities) without increasing the interrupting duty of ac circuit breakers.

The relationship of cable length to the choice of an ac or dc transmission voltage lies in the capacitance of the cable. As the ac cable length and voltage increase, the capacitance, and hence the ac charging current, increases in proportion (charging current is equal to the voltage divided by the cable’s capacitive reactance). At the so-called critical length, the capacitance charging current equals that of the thermal current rating of the cable, and no real power can be transmitted. For short- to medium-length ac cable systems, the charging current can be compensated for by the use of shunt reactors at the cable terminations, or in the case of submarine cables, at intermediate islands. For long cable lengths, however, this becomes impractical, and dc power transmission is necessary.

Recently there is a considerable interest in using HVDC cables for renewables’ (for example, wind and solar) integration as well as power grid interconnections. Submarine HVDC cables are being considered for off-shore wind integration in many parts of the world. Though HVDC cables have been used for some time, there is a need for understanding these technologies for new applications.

**Project Approach and Summary**

The objective of the EPRI HVDC Cable Interest Group is to address both underground and submarine cable issues for different applications. EPRI will lead this Interest Group with the member participation from electric utilities and manufacturers. This Interest Group can provide information and research results in the following areas:

- Operational experience of existing dc cables
- Mechanical & electrical issues
- State-of-the-art knowledge and economic choices
- DC cable type selection
- Voltage-source-converter-based dc applications
- Challenges and opportunities presented by cable technologies

Initially it is proposed to have a series of conference calls among all participants to identify and prioritize the technical issues. Also depending on participation, one or more technical workshops per year will be organized to exchange information among all participants. This Interest Group also will identify areas for further research that can be separately undertaken using EPRI supplemental funding.
Benefits

- Increase understanding about HVDC cable technology applications
- Share the experience with other participants and learning from each other on HVDC cables
- Identify technology R&D needs in HVDC cables
- Reduce the costs of power transmission, potentially reducing electricity rates to end-use customers
- Increase overall system controllability, stability, and reliability
- Make informed decisions based on technical and economic aspects of HVDC cable technologies
Grid Operations - Program 39

Program Overview

Program Description

In many ways, today's power system must be operated to meet objectives for which it was not explicitly designed. Today's transmission system is operated to transfer larger amounts of energy than were considered when it was built, and it is operated much closer to the margin. Generation resources are more constrained and increasingly more variable and uncertain. Demand resources are now a viable option for providing ancillary services in many regions. Under these circumstances, it is imperative that operators be provided with good information based on real-time data regarding the status of the system, as well as decision-making support information to respond to rapid changes in the future. The emergence of new sources of real-time data that are becoming available from synchrophasor measurements and forecasts of coming load and variable renewable output levels enable the possibility of providing operators with increased situational awareness and advanced decision-support tools to reliably and economically operate the system in the face of emerging challenges. EPRI's Grid Operations research program is addressing these needs by improving real-time situational awareness, wide-area protection, reactive power support, and voltage stability margins, as well as the capabilities to manage the grid through extreme events and to restore the system in the event of an outage.

Research Value

The mission of EPRI's Grid Operations research program is to support the development of next-generation monitoring, analysis, and control capabilities that will be required to operate the transmission grid in the most reliable and economic manner as the generation mix and capabilities change significantly and as load becomes a more prevalent system resource. In 2012, EPRI's Grid Operations research program will offer its members a focused research portfolio with the objectives of:

- Improving system reliability and reducing operational risks through the improved situational awareness of operators, including the incorporation of equipment health information into the control room and the identification of operating boundaries and margins
- Supporting operators in ensuring that steady-state and post-contingency system voltage performance is maintained, utilizing the optimal mix of available reactive resources
- Reducing the risk of wide-area events and improving restoration time in order to reduce outage costs through restoration optimization methods and guided control decision making when separation may be the best choice
- Developing advanced analysis algorithms that utilize synchrophasor data to support operator situational awareness and decision support

Approach

EPRI's Grid Operations research program delivers value utilizing the shared experiences and understanding of its utility and independent system operator (ISO) members in conjunction with the expertise of EPRI's staff and network of top-level contractors to conduct research projects that lead to actual methods and tools used by system operators. EPRI also engages with external industry standards, regulatory, and research efforts to ensure that the EPRI research program is taking advantage of the broader industry efforts and advancing the state of the art. Our research program also strives to provide members both short- and long-term value. For example, the 2012 Grid Operations research program will continue the development of innovative methods and software tools for supporting system restoration needs that can occur at any time, while at the same time beginning research to investigate advanced data processing, computing technologies, and solution algorithms to improve the performance of all operational analytics and decision making.
Accomplishments

EPRI's Grid Operations program has provided critically needed technologies and information for its members over many years. Examples include:

- **Generic Operator Training Simulator (OTS), Version 2.0:** The EPRI Generic Operator Training Simulator is a PC-based training simulator that allows hands-on training for dispatchers, using a generic 29-station model. The Generic OTS, which can be run on multiple platforms, allows for realistic simulations of many power system phenomena. Users may employ a generic power and light model or incorporate their own models into the OTS. The generic OTS has also been integrated with several Energy Management System (EMS) vendors.

- **Situation Awareness (SA) in Power System Operations:** This technical update represents a detailed study of the use of color, automated systems, and predictive SA tools in the power industry. Data were gathered through site visits to three control centers and an online color survey. A total of 27 survey responses from 25 separate EPRI members was collected and analyzed.

- **Prototyping a Decision-Support Tool for the Evaluation of System Restoration Strategy Options:** This project studied industry practices and documentation of system restoration plans. A new concept, Generic Restoration Milestone (GRM) during system restoration, was proposed. Based on that, a prototype decision-support tool for evaluating system restoration strategy options was developed. A specific restoration strategy can be established by a combination of GRMs based on system characteristics, energy sources, and constraints of power grids, and then it can be examined through simulations. Different combinations or sequences lead to different strategy options and performances. Simulation studies have shown that the developed decision-support tool enables a power system in a blackout status to restart and self-organize various parts of the system until it achieves complete restoration.

Current Year Activities

In 2012, EPRI's Grid Operations research program will offer its members a focused research portfolio with the objectives of:

- Improving system reliability and reducing operational risks through the improved situational awareness of operators, including the incorporation of equipment health information into the control room and the identification of operating boundaries and margins
- Supporting operators in ensuring that steady-state and post-contingency system voltage performance is maintained, utilizing the optimal mix of available reactive resources
- Reducing the risk of wide-area events and improving restoration time in order to reduce outage costs through methods and guided control decision making when separation may be the best choice
- Developing advanced analysis algorithms that utilize synchrophasor data to support operator situational awareness and decision support

Estimated 2012 Program Funding

$3.0M

Program Manager

Daniel Brooks, 865-218-8040, dbrooks@epri.com
Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>P39.011</td>
<td>Situational Awareness Using Comprehensive Information</td>
<td>This project will help improve system operators’ situational awareness. By visualizing comprehensive operating boundary/margin information, operators would be aware of “where we are” (the operating conditions and status of critical equipment), “how far we can go” (security margins) and “what we should do” (decision support for control actions).</td>
</tr>
<tr>
<td>P39.012</td>
<td>Online Reactive Power Management and Voltage Control</td>
<td>This goal of this project is to develop advanced study techniques, mitigation measures, and decision-support tools for grid operators and planners to address potential voltage stability problems.</td>
</tr>
<tr>
<td>P39.013</td>
<td>Decision Support Tools for System Emergency and Restoration</td>
<td>This project will investigate critical system operation functions and develop tools to help system operators with decision support in mitigating extreme disturbance events, especially natural disasters, and in restoring power systems.</td>
</tr>
<tr>
<td>P39.014</td>
<td>New Computing Technologies for Grid Operations</td>
<td>This project will investigate, identify, and develop advanced data processing and computing technologies for control centers to improve online simulation performance in speed, accuracy, and the range of scenarios considered.</td>
</tr>
<tr>
<td>P39.015</td>
<td>Synchrophasor Applications</td>
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</table>

P39.011 Situational Awareness Using Comprehensive Information (070591)

Key Research Question

Situational awareness is critical for grid operators to maintain system reliability and minimize major power outages. At present, the rapid growth of regional electricity markets, increasing integration of variable generation resources, and lack of corresponding growth in transmission infrastructure result in more uncertainties in daily grid operations. These changes could result in the transmission system operating even closer to its limit and, thus, increase the likelihood of stability issues during disturbances or equipment failures.

The North American Electric Reliability Council (NERC) developed the concept of “boundary conditions” to point out the importance of real-time operating boundary/margin information for grid operators to be aware of “where we are” (that is, the operating point), “how far we can go” (that is, security margins) and “what we should do” (that is, control actions). In 2011, EPRI started the development of visualizing online operating boundary/margin information and the functional specification for related software development. The developed scheme can interface with existing security assessment techniques to visualize comprehensive operating boundaries and margins in terms of thermal limits, voltage security limits, transient stability limits, and other limits.

In addition, the health status of critical power system equipment can help operators recognize potential equipment failures and allow them to take proactive actions, such as unloading a transformer that has shown signs of fatigue. In addition to protecting equipment life, this information allows operators to better assess potential contingencies that might impact reliability. In the past two years, EPRI concentrated functional specification studies on generic equipment classes, identified technology gaps, and developed a roadmap to integrate equipment health information into control centers. This work will continue to integrate and implement equipment health information to improve the system operations awareness of critical components.
**Approach**

In 2012, the EPRI project team will develop a prototype software application based on the developed functional specification for online visualization of operating boundaries and margins. The application would utilize an operator-friendly graphical user interface (GUI) with concise, easy-to-use displays. Comprehensive boundary/margin information would be visualized about user-definable observation variables, for example, interface power flows, regional loads, and main generator outputs. Its interfaces with online measurements (for example, from SCADA/EMS and synchrophasors) will be developed to estimate the system operating condition. The interfaces with commercialized power system security assessment tools (for example, PSS/E) will also be defined to perform timely updates of operating boundaries and margins under both pre- and post-contingency conditions.

For integration of equipment health information, the EPRI project team will develop prototype displays for general classes of equipment based on the functional specifications developed previously. The EPRI project team will work closely with the area experts in equipment diagnosis and communications to address identified technical gaps in the roadmap developed earlier. For example, if there is a certain class of equipment that is deficient in presenting a particular type of health information that the control center would like to have, the EPRI team will work with equipment diagnostics experts to determine a conceptual model for a monitoring device to address the issue.

**Impact**

- Improve system operators’ situational awareness by comprehensive operating boundary/margin information.
- Improve system operators’ monitoring capabilities on critical equipment and potentially dangerous situations.
- Possibly reduce the risk of cascading outages caused by insufficient operating margins or equipment failures.

**How to Apply Results**

Members can integrate the software application for online visualization of operating boundary/margin information with their SCADA/EMS systems and security assessment programs. The technical results on integration of equipment health information would provide guidelines and techniques for monitoring critical system equipment. EPRI would work with members to apply the results from the project through supplemental projects.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online visualization tool for comprehensive operating boundary information: This software is to be used for visualizing comprehensive operating boundary and margin information.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td>Integration of Equipment Health into Control Centers: The technical update will address technical gaps in the integration of equipment health information into control centers and provide guidelines on monitoring critical system equipment.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

**P39.012 Online Reactive Power Management and Voltage Control (070592)**

**Key Research Question**

Voltage stability is a major concern in system operation and a leading factor that limits power transfers. Increasing variable generation and the changing dynamic characteristics of loads bring more challenges to maintain voltage stability in the operating environment.
Identifying potential voltage instability areas and determining the required reactive power reserve in real time are technical challenges that need to be solved. There are also increasing research needs regarding techniques for optimally managing dynamic VAR reserves to ensure fast voltage recovery, as well as techniques for sensing voltage recovery following disturbances.

Current state-of-the-art technologies for voltage stability analysis are based on simulations of what-if scenarios to study potential voltage stability issues. Deploying more synchrophasors opens up the opportunity of using synchrophasor data to perform voltage stability analysis in real time. Combining the measurement-based and simulation-based approaches to help system operators better monitor and control voltage stability is the technical issue to be solved.

Approach

EPRI has developed advanced study techniques for short-term and long-term voltage stability phenomena.

1) Voltage Control Area (VCA) Technique: EPRI has developed VCA software to investigate steady-state voltage stability performance, identify potential voltage instability areas, and assess optimal reactive power allocation. The 2012 efforts are expected to focus on demonstrating the applicability of the software on a large, realistic power system.

2) Hybrid Online Voltage Stability Monitoring: EPRI has developed a measurement-based voltage stability monitoring (MB-VSM) technique to derive the voltage stability margin at a substation or a defined network interface in real time, based on high-resolution measurement data (for example, from synchrophasors). The 2012 efforts are expected to focus on developing a method for real-time hierarchical voltage stability assessment at substation, load center, and system levels, combining both measurement-based and simulation-based approaches. A graphical user interface will also be developed to facilitate an operator's decision making.

3) Optimal Reactive Power Allocation (ORPA) Method: EPRI has developed this method to investigate short-term voltage stability phenomena and identify optimal allocation of reactive power resources. The 2012 efforts are expected to focus on demonstrating the applicability of this method on a large, realistic power system.

4) Coordinated Voltage/VAR Control Strategy Utilizing Variable Generation (VG) and Distributed Energy Resources (DER): In addition to conventional voltage support and reactive power resources, dynamic VAR systems operating at the grid interface of wind farms and switching converters inside DER are other devices that can provide reactive power and dynamic voltage control. In 2012, we will investigate how a coordinated control strategy can be developed to optimize the reactive capability of these devices for improved voltage support.

Impact

- Provide guidance on study tools/techniques/procedures/modeling for investigating voltage stability.
- Identify mitigation measures.
- Provide situational awareness for potential voltage stability issues.
- Facilitate decision making to help avoid or mitigate a potential voltage instability scenario.

How to Apply Results

A member can implement the project results as follows:

- Use technical reports to enhance voltage stability investigation by improving study procedures, using advanced tools, and developing improved modeling. This will be useful to grid operations staff in real-time contingency analysis and to planning staff in off-line studies.
- Use VCA software to conduct voltage stability investigations by importing PSS/E or PSLF data to the VCA software.
- Employ on-line visualization tools in the control center to know the system voltage and reactive reserve status and to facilitate decision-making.
## 2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Reactive Power Management to Address Long-Term Voltage Stability Using Voltage Control Area (VCA) Technique: Members can use Voltage Control Area (VCA) software to conduct voltage stability investigations by importing PSS/E or PSLF data to the software. This will be valuable to grid operators and planners with regard to assessing potential steady-state instability scenarios on their systems. This will facilitate grid operators' decision making to help avoid or mitigate a potential voltage instability problem.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td>Reactive Power Management to Address Short-Term Voltage stability Using Optimal Reactive Power Allocation Method: A member can use the above deliverable to enhance voltage stability investigation by improving study procedures, using advanced tools, and developing improved modeling. This will be useful to the grid operations staff in real-time contingency analysis and to the planning staff in off-line studies. Such studies are expected to help grid operators and planners with regard to potential fast voltage collapse scenarios on their systems and in identifying mitigation measures.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td>Online method for hierarchical voltage stability assessment at substation, load center and system levels: A member can implement the project results by employing on-line visualization tools in the control center to learn the status of potential voltage instability problems. This will be valuable in facilitating an operator's decision making.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

### P39.013 Decision Support Tools for System Emergency and Restoration (070593)

#### Key Research Question

System restoration is important operation function to minimize the impacts of major disturbance events. The occurrence of natural disasters is one example. The impact of such events on electric power system functioning has been of interest to countries worldwide. Effective system control and restoration can promptly bring a system in blackout or separation status back to service. However, for system restoration, operators need online tools to evaluate restoration strategy options and efficiently determine restorative actions without causing security violations. Special considerations need to be taken in such emergencies. System operators need special control plans and strategies in preparation against natural disasters.

#### Approach

In 2009-2011, EPRI prototyped a decision-support tool for evaluating restoration strategy options. Based on the developed techniques, this project will develop, enhance, and demonstrate software applications for intelligent system restoration. The decision-support tool for system restoration will be further enhanced to integrate into operator training simulators (OTS) and later with EMS.

In addition, the team will look at specific disasters worldwide and assess critical functions of control centers under emergency conditions. Critical functions may include, but are not limited to, (a) dispatch and grid operations, (b) system restoration plans and protocols, and (c) communication (data management and analysis, and data/information transmittal to control centers).

#### Impact

- May assist in developing precautionary emergency control plans and strategies against natural disasters.
- May shorten system restoration time to reduce loss.
- Improve system operators’ confidence when making decisions.
How to Apply Results

Findings and functions developed for control centers under emergency conditions may be used in emergency control centers to curtail the impact of disasters on the power system and to carry out recovery actions in order to minimize social disruption. System operation staff may use the system restoration decision-support tool in training to improve their knowledge of effective restoration strategies. EPRI may offer training courses and supplemental project opportunities to help members apply the tools.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional Specification for System Emergency Grid Operation Tools in Natural Disasters:</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Develop functional specifications for control centers under emergency conditions to curtail the impact of disasters on the power system and to carry out recovery actions in order to minimize social disruption.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decision support tool for system restoration: This decision-support tool is designed for system restoration engineers to develop and evaluate restoration strategies, which will reduce restoration times and facilitate better communication of restoration steps across all stakeholders.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
</tbody>
</table>

P39.014 New Computing Technologies for Grid Operations (070594)

Key Research Question

To manage the added complexity in the power system, the operator’s job can be facilitated by deploying advanced computing technologies, which can include new simulation techniques, software, and hardware, that can potentially accelerate data analysis and computer simulation tasks. There are a number of ways to improve simulation performance that can be explored:

- Improved information – Utilities are installing more and more sensor technologies, such as synchrophasors and line sensors, so that faster, more intelligent data processing is needed to quickly filter raw data into concise information.
- New modeling structures – Various model structures can allow for faster and/or more accurate mathematical operations.
- Advanced mathematical solvers – New, advanced computational mathematic techniques can improve simulation speed and accuracy.
- Advanced software and hardware technologies – Technologies such as, but not limited to, reduced instruction set computer (RISC), graphic processor unit (GPU), multi-core, distributed computing, and virtualization may improve simulation speeds or investment costs and utilization.

There are many technologies to consider, and there are technologies that can complement each other. This project will focus on identifying the near-term application enhancements that can utilize the most complementary methods listed above to improve simulation performance in speed, accuracy, and the range of scenarios considered for system operations.

Approach

The 2011 project results will highlight the best near-term technologies and methods for improving online simulation and analysis tasks and set the guidelines for a few specific applications that are mature enough for near-term implementation. The 2012 scope will continue to monitor the developments in the investigated computational technologies and begin to integrate the guidelines set forth in the 2011 results. The main objectives of the 2012 work will be further development of functional specifications for integrating the key applications identified in 2011 through detailed description of the algorithm and modeling structure to begin to
address practical issues, an offline case study to demonstrate the feasibility of selected applications, and an investigation of the impacts of the targeted applications’ modification on other applications.

**Impact**

- May reduce the risk of cascading outages by improving online simulation and analysis techniques.
- May provide an advanced computing foundation for the new smart grid environment in which a greater abundance of online data exists.
- Improve the utilization of existing or introduce new low-cost computing technologies into control centers.

**How to Apply Results**

Implementation guidelines for integration and case study results will be documented in a report. EPRI may provide application services to help members apply these technologies.

**2012 Products**

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation Plan for Advanced Data Processing, Mathematical Techniques and Computing Technologies to Enhance Simulation Tasks:</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

**P39.015 Synchrophasor Applications (072024)**

**Key Research Question**

Synchrophasors are precise grid measurements that are now available from monitors called *phasor measurement units* (PMUs). Because they have the capability of directly measuring phase angles at high sampling rates and accuracies, synchrophasors are prompting a revolution in power system operations as next generation measuring devices. As with the smart grid investment grants and demonstration projects funded, an additional 850 PMUs are going to be installed, which will bring the United States total to over 1,000 in the next three years.

The objective of this project is to accelerate the development and adoption of PMU analytics. In 2012, this project will focus on the following two analytics:

1. Real-time event processing and analysis tool
2. Comprehensive online stability analysis

**Approach**

This project will first review the present techniques related to real-time event processing and synchrophasor-based stability analysis. The project will then incorporate the following two aspects:

- **Real-time event processing and analysis tool**: Propose an integrated environment for analyzing synchrophasor data event detection and location algorithms identified as most useful (the 2010 project Synchrophasor Success Stories will provide the basis for the research); develop a critical event recognition algorithm that has intelligent learning capability; and write up the overall functional requirements for an integrated event-analysis tool.
• **Comprehensive online stability analysis**: Investigate trajectory analysis on synchrophasor measurements for stability analysis. This investigation may integrate analytical tools for both small-signal stability (for example, modal analysis) and large-signal stability (for example, the energy function) to provide an early warning of potential instability under a long sequence of disturbances. Based on those investigations, develop a methodology for optimizing the design or configuration of a synchrophasor network for online stability analysis.

**Impact**

- Improve system operators’ situational awareness and reliability through real-time recognition of events as they happen.
- Improve system operators’ capability to monitor and control the stability of the transmission system.

**How to Apply Results**

Members will be trained through webcasts and workshops on the concepts and methodologies of this project. New tools developed in this project will be provided to members for testing on their systems, and the results will be shared among members to enhance the experience and apply the technical results of this project.

**2012 Products**

<table>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Comprehensive Stability Analysis Using Synchrophasors</strong>: This technical update will document new methodologies and study results.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Functional Requirements for Real-Time Event Analysis Tool</strong>: This technical update will provide the functional requirements for the next generation real-time event-analysis tool.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
Supplemental Projects

Guidelines for Implementing Dynamic Thermal Circuit Rating (DTCR) in Systems and Market Operation (072025)

Background, Objectives, and New Learnings

Experience with a number of utilities indicates that the ratings of power equipment via dynamic thermal circuit rating (DTCR) are typically 5%–15% higher than conventional static ratings. EPRI Programs 35 (Overhead Transmission) and 37 (Substations) are investigating the ability to forecast DTCR one day ahead, based on weather forecasts. Can the combination of these new capabilities increase system benefits and minimize operational risks?

Application of dynamic ratings may enhance economical operation by enabling less-constrained operation and timely mitigation action that avoids dangerous system security conditions by tracking the thermal state of equipment. Significant economic benefits from increased use of DTCR are also possible through the use of forecasting. To make efficient use of such forecasts, system and market operators need to know how much to safely relax thermal ratings to achieve economic benefits without increasing operational risk.

Project Approach and Summary

EPRI proposes to perform various demonstration studies of control areas, investigating how dynamic line rating can be integrated into system and market processes including how prices and energy dispatch may change throughout the network. A second focus will be to determine the changes in requirements for reserves and their allocations. These investigations may include:

- Methods to quantify economic benefits without increasing operational risks
- Impact of dynamic line rating on contingency analysis
- Options that the system operator has to react to real-time DTCR changes
- Relationship between increased line ratings and path throughput
- Economic benefits from relaxed line ratings
- Accuracy requirements for DTCR forecasts to meet operational and market needs

Benefits

Successful completion of this project could:

- Help operators take advantage of increased power equipment utilization.
- Increase transmission capability and bring economic benefits to consumers.
- Improve operators’ ability to respond to real-time DTCR changes.
- Improve system reliability.
- Help system operators avoid false congestion and security alarms by providing sound operating limits through real-time ratings of system equipment.
- Provide sound engineering judgments in applying dynamic ratings to operational decision making.
Feasibility Assessment for Implementing Advanced Voltage Control (072026)

Background, Objectives, and New Learnings

Voltage profile and stability are important concerns in planning and operating electric power systems with increased power flow. One of the important operating tasks of power utilities is to keep voltage within an allowable range for high-quality customer services. Electric power loads vary from hour to hour, and voltage can be varied by the change of the power load. Power utility operators use a variety of equipment, such as generators, transformers, static condensers (SC), and shunt reactors (ShR), to control voltage.

Traditionally, voltage is controlled in a decentralized way at the power plant or substation level. Hence it lacks wide-area coordination and optimization among local voltage controllers, such as automatic voltage regulators in power plants. Voltage violations and unexpected massive reactive power transfers occur sometimes.

In recent years, system-wide hierarchical dynamic voltage control (HDVC) has been investigated, developed, and implemented in some systems. While power systems are experiencing ever-increasing varying loading conditions, the sophisticated HDVC process can effectively maintain a steady voltage within preset limits. HDVC systems have the potential to reduce transmission system loss, increase system MVAR reserve, and improve system reliability for pre-contingency and post-contingency.

To better understand HDVC technology and implement the technology into the power system, EPRI is working with pioneering researchers and investigators to evaluate the feasibility for implementing HDVC technology. This group is also investigating possible practical considerations and issues to deploy the technology in actual systems. The deployment of HDVC systems is expected to achieve better voltage performance and improve reliability, quality and economy in system operation.

Project Approach and Summary

EPRI will work closely with each project member to identify specific details and issues for a successful implementation. This will be done with conference calls, webcasts, and presentations of system conditions and optional implementation schemes. This methodology is intended to help participants understand their needs for a future implementation. The reporting of case studies and analysis helps utilities and system operators plan their own detailed implementation.

Benefits

This study assists system engineers in understanding the outcome of hierarchical dynamic voltage control system deployment in:

- Controlling system voltage profile
- Reducing transmission system loss
- Increasing system MVAR reserve
- Improving system reliability for pre- and post-contingency
Early Warning of Potential Wide-Area Stability Problems Using Synchrophasors (072027)

Background, Objectives, and New Learnings

Large power system blackouts, although infrequent, may influence up to tens of millions of people and result in huge costs. Usually, a major power outage is not caused by a single fault; rather, it is more likely to be the result of a sequence of disturbances, including initial events, additional failures, consequent protective actions, increasingly vulnerable conditions, and accelerated cascading outages, leading to a loss of stability. Those disturbances may gradually weaken a power system’s connections and result in growing inter-area angular oscillations. If not damped, oscillations may evolve into a loss of synchronism between two or more groups of generators and even system islanding.

Increasing deployment of synchrophasors, for example, phasor measurement units (PMUs), on transmission systems can provide opportunities for monitoring of real-time wide-area power system dynamics. However, available applications of synchrophasors are mainly in displaying and visualizing their measurements. Grid operators need advanced applications that are able to turn raw measurements into more meaningful knowledge, such as online security margins, risks of stability problems, and indication of potential cascading outages. Since 2008, EPRI has conducted research and development on the application of synchrophasors in the early warning of potential wide-area stability problems involving increasing oscillations and loss of synchronism between interconnected regions. EPRI filed a U.S. patent application in 2010 on a synchrophasor-based algorithm for predicting the loss of synchronism in interconnected power systems.

Project Approach and Summary

Based on EPRI’s accomplishments in synchrophasor applications, this project will develop a software engine for the early warning of potential wide-area stability problems using synchrophasor data. If fed with a time series of synchrophasor data at dispersed locations, the software engine would offer the following functions:

- For user-definable regions (that is, groups of synchrophasors) in a power system, dynamically identify dominant inter-area oscillations between those regions and the related mode shapes.
- Among those regions, dynamically identify the most dangerous interfaces of angle separation.
- Conduct a stability assessment on the dynamically identified interfaces to estimate the angular stability margin.
- Provide a real-time warning on the potential loss of synchronism if the stability margin on any interface is found below the expected level.

The outputs of the software engine include modal information on dominant inter-area oscillations and the estimated values of stability margin indices. The project will define the software’s data interfaces to phasor data and visualization tools so that the participants of the project can easily test the software engine on their grids and integrate it into their real-time monitoring systems.

Benefits

- Provide wide-area angular stability monitoring using synchrophasors.
- Provide real-time trends on the angular stability margin during a sequence of disturbances.
- Indicate the critical grid interfaces where stability problems may potentially happen and proactive control actions should be added.
- Possibly reduce the risk of cascading outages by providing early warning of insufficient stability margin so that a grid operator can employ pre-defined operating procedures on a timely basis.
Grid Planning - Program 40

Program Overview

Program Description

Traditional power system planning methods and tools are becoming less effective in today’s power system environment. Transmission owners and operators not only need to plan for future demand growth, which is more uncertain with increasing levels of distributed resources, but also to provide transmission services for changing generation portfolios that include significant portions of variable generation technologies that are often remote from load centers and have significantly different dynamic behavior from synchronous generation. The challenge of meeting reliability requirements with the addition of variable generation and allowing demand response as a capacity resource may necessitate transmission planning to reassess planning objectives as planning for peak load scenarios will not be sufficient. Resource planners are also increasingly challenged as environmental regulation forces the retirement of some conventional generation, supply resources become more variable and uncertain, and distributed and demand-side resources become more viable. Resource adequacy may no-longer be defined simply by ensuring sufficient capacity, but rather will include ensuring the right kind of capacity that exhibits sufficient flexibility to accommodate more variability and uncertainty from renewable and demand resources.

EPRI’s Grid Planning research program is designed to address the following strategic issues that grid planners must resolve by developing methods and tools for planners to offer operators a system that can be operated reliably and economically:

- The increasing uncertainty of future generation and load
- Increased use of transmission assets and rights of way
- Higher reliability standards
- Greater regional planning

Research Value

The mission of EPRI’s Grid Planning research program is to support the development and validation of planning study models, planning processes and frameworks that incorporate reliability and economics, and various reliability assessment analytics that will be required to build a reliable and economic transmission grid that integrates and uses an evolving generation mix to supply an increasingly complex load that can also act as a system resource. In 2012, EPRI’s Grid Planning research program will offer its members a focused research portfolio with the following objectives:

- To develop and validate static, dynamic, and short-circuit models of system components such as static volt-ampere-reactive (VAR) systems and high-voltage direct-current (HVDC) components
- To develop probabilistic and risk-based planning methods and tools for explicitly incorporating traditional and emerging sources of uncertainty in the system
- To develop tools and methods for ensuring that system protection and control aspects are adequately considered and incorporated in the planning process
- To develop a system planning framework and associated tools to ensure that sufficient flexibility exists in the system in the most economic manner to meet the system’s increasing variability and uncertainty requirements
- To develop metrics and tools for determining frequency response adequacy for a given interconnection and balancing authority and evaluating the effect of emerging regulations on the frequency response adequacy of a given system
Approach

EPRI's Grid Planning research program delivers value by using the shared experiences and understanding of its utility and independent system operator (ISO) members in conjunction with the expertise of EPRI's staff and network of top-level contractors to conduct research projects that lead to actual methods and tools used by system planners. EPRI's Grid Planning program also engages with external industry standards, regulatory, and research efforts to ensure that the EPRI research program is using broader industry efforts and advancing the state of the art. For research areas whose deliverables are of value only if embraced by the larger industry, as is the case for the development of new models that need to be adopted in commercial analysis packages, we work to engage in the industry efforts and share our research publicly to drive the industry to the desired path agreed on with our members. Our research program also strives to provide members with both short- and long-term value. For example, the 2012 Grid Planning research program will continue to develop and validate system component dynamic models already prevalent in the grid while investigating ways in which resource adequacy planning processes need to change to ensure that the system of the future has enough capacity to meet system demand and has the right kinds of capacity to respond to increasing system variability and uncertainty.

Accomplishments

The Grid Planning program delivers valuable information that helps its members and the industry in numerous ways. Some examples include:

- **Power Plant Parameter Derivation (PPPD) Version:** The PPPD software uses measured synchronous generator responses to system disturbances to validate the generator, excitation system, and governor control system transient stability models. PPPD performs an automated optimization algorithm to determine the parameter values for the selected model structures that provides the best match to the measured disturbance responses. This tool allows transmission planners and generation owners to perform ongoing model validation as system disturbances occur and to comply with emerging North American Electric Reliability Corporation (NERC) MOD-26 and MOD-27 requirements to periodically supply validated model parameters.

- **Probabilistic Risk Assessment (PRA) Version 4.1:** The PRA software reads load-flow text files and probabilistic information and then computes and displays reliability indices through a graphical user interface. When applied to power delivery systems, this methodology offers the ability to determine the probability or likelihood of an undesirable event on the transmission system as well as a measure of its severity. PRA combines a probabilistic measure of the likelihood of undesirable events with a measure of the consequence of the events into a single reliability index—the probabilistic reliability index (PRI).

- **Utility Application Experiences of Probabilistic Risk Assessment Method:** This technical report summarizes recent utility experiences applying EPRI's PRA methodology, which offers greater accuracy than traditional deterministic approaches for assessing grid reliability. PRA methodology has been used by many utilities since 2001, and sufficient data are now available for the power industry to move toward widespread implementation. These studies allow system planners to receive complementary information in addition to traditional deterministic contingency analysis results. Displaying deterministic and PRA results through charts, tables, and maps enables the effective visualization of complex reliability information.

- **Comprehensive Load Modeling for System Planning Studies:** This technical report presents valuable information related to both measurement-based and component-based load modeling. It also presents a clear, step-by-step approach to current best practices in comprehensive load modeling for planning studies. Detailed data on laboratory tests of key load components—such as air conditioners, compact fluorescent lighting, and high-definition televisions—are presented. Results of measurement-based load model parameter derivation attempts and lessons learned from these exercises are also provided.

Current Year Activities

In 2012, EPRI's Grid Planning research program will offer its members a focused research portfolio with the following objectives:
To develop and validate static, dynamic, and short-circuit models of system components such as static VAR systems and HVDC components

To develop probabilistic and risk-based planning methods and tools for explicitly incorporating traditional and emerging sources of uncertainty in the system

To develop tools and methods to screen the most serious fault locations for angular and voltage stability criteria

To develop tools and methods for ensuring that system protection and control aspects are adequately considered and incorporated in the planning process

To develop a system planning framework and associated tools to ensure that sufficient flexibility is developed in the system in the most economic manner to meet the system’s increasing variability and uncertainty requirements

To develop metrics and tools for determining frequency response adequacy for a given interconnection and balancing authority and evaluating the impact of emerging regulations on the frequency response adequacy of a given system

**Estimated 2012 Program Funding**

$2.0M

**Program Manager**

Daniel Brooks, 865-218-8040, dbrooks@epri.com

### Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P40.016</td>
<td>Planning Study Model Development and Management</td>
<td>This project helps system planners improve modeling accuracy and the model management process.</td>
</tr>
<tr>
<td>P40.017</td>
<td>Transmission Network Analysis Methods and Tools</td>
<td>This project helps system planners improve reliability assessment capabilities and meet NERC reliability criteria.</td>
</tr>
<tr>
<td>P40.018</td>
<td>Protection System Simulator</td>
<td>The goal of the subject project is to develop a software-based time-domain system protection simulator that is capable of providing results comparable to more costly hardware-based solutions, that is, real-time simulators (RTSs).</td>
</tr>
<tr>
<td>P40.019</td>
<td>Strategic and Flexible Transmission Planning</td>
<td>This project will build an industry consensus framework for strategic and flexible transmission planning to meet the reliability and economic needs of an increasingly dynamic power system.</td>
</tr>
<tr>
<td>P40.020</td>
<td>Frequency Response Adequacy</td>
<td>The project is aimed at taking a closer look at frequency response metrics, that is, how we assess the frequency response of a power system and how can we effectively measure it. The next step is to take an example system and, through the development of a step-by-step study approach, look at the frequency response of the system and identify the factors that affect adequacy.</td>
</tr>
</tbody>
</table>
P40.016 Planning Study Model Development and Management (070595)

Key Research Question

Computer simulation models of power systems are needed to facilitate an effective and reliable means of planning, designing, and operating the bulk power system.

This project will be a continuation of the P40.016 project from 2011. In 2010, EPRI worked in collaboration with WECC, through an open forum (the WECC SVC TF), to develop generic models for shunt FACTS devices: static var systems (SVS). Three new models were developed to allow one to represent in power flow and dynamics, for planning studies, the behavior of SVCs and STATCOMs. These models have been adopted by two major software vendors (GE PSLF® and Siemens PTI PSS®E) and will likely be adopted by others. The models and documentation were shared publicly to allow all software vendors who wish to do so to adopt the models. In 2011, the work continues to ensure the final completion of the SVS models, to start work on HVDC models for planning, and to address issues related to generator and turbine-governor modeling.

The objectives of this project are to continue these efforts in providing similar value for developing models, model validation, and documentation for other technologies such as voltage source HVDC.

Approach

- Continue to develop generic models for the dynamic analysis of transmission and conventional generation equipment. This includes models for HVDC, FACTS, and aspects of synchronous generator modeling that require further R&D (for example, newly proposed gentpj model in Western Electricity Coordinating Council [WECC] and issues related to long-term dynamics of turbine-governor response).
- Hold meetings and workshops in collaboration with WECC and NERC, as appropriate, related to modeling, model development, and model validation.
- Continue to work on load modeling.

Impact

- Help planning and operations engineers accurately model various components of the power systems.
- Provide new and improved models that are accepted industrywide and publicly disseminated so that they are quickly adopted by commercial software vendors and supported by equipment vendors.
- Improved power system reliability through improved modeling and simulation capabilities to more effectively plan the system.

How to Apply Results

The results will be disseminated through public forums (for example, WECC) to facilitate the adoption of the newly developed models (as with the example of the SVS models developed) by commercial power system simulation software vendors. Results will also be shared when appropriate workshops will help in collaboration with NERC, WECC, and other stakeholders to disseminate the latest knowledge on the use and application of newly developed models.
## 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td><strong>Technical Update on Planning Study Model Development and Management:</strong> The technical update will summarize the work done in 2012 related to the development of model and model validation work. The results will be disseminated through public forums (e.g. WECC) so as to facilitate the adoption of the newly developed models (like the example of the SVS models developed in previous years) by commercial power system simulation software vendors. Also, when appropriate workshops will be help in collaboration with NERC, WECC and other stakeholders to disseminate the latest knowledge on the use and application of newly developed models.</td>
<td>12/31/12 Technical Update</td>
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</table>

### P40.017 Transmission Network Analysis Methods and Tools (070596)

#### Key Research Question

New tools and transmission reliability assessment and planning methods are needed to help transmission planners conduct studies that comply with whatever reliability criteria are adopted. The direction of these emerging reliability standards is toward more comprehensive assessment of single and multiple contingencies with or without cascading effects and with ranges of consequences in terms of overloads, voltage violations, and load curtailments to prevent voltage collapse.

The purposes of this project are to perform a proof-of-concept study for the Fast Fault Screening (FFS) methodology for transient stability analysis, both angular and voltage stability, and to initiate new research on evaluating potential cascading modes.

#### Approach

- Develop a fast contingency screening tool for stability studies: EPRI might develop a tool that can screen thousands of potential transmission fault locations and quickly identify the most severe locations. This work might consider not only transient stability, but also the inter-area oscillation problem.
- Investigate transmission availability statistics and develop methods for studying high-order contingencies: EPRI might continue the research in this area to use NERC TADS to develop a probabilistic measure of likelihood for various categories of contingencies. It seems possible for the various contingency events in the current Tables 1 and 2 to be re-categorized into five or six groups based on "order of magnitude of likelihood." Each order of magnitude of likelihood is 10 times less likely than the preceding order.
- Develop a tool that can simulate cascading outages and predict the boundaries and load of the impacted area.

#### Impact

- Reduce computation time and save work-hours for NERC reliability standards compliance-related studies.
- Provide a practical tool to perform transient stability studies required under the forthcoming NERC standard TPL-001-1.
- Quantify the impact of severe contingencies.
- Quantify the degree of robustness of a transmission grid.
- Enable more comprehensive reliability assessment of transmission plans.
How to Apply Results

The advanced reliability assessment method can be used by utilities, ISOs, and regional transmission organizations (RTOs) to evaluate the robustness of transmission plans and the extent to which they satisfy existing NERC reliability standards. EPRI will offer supplemental project opportunities to apply the methods and tools developed through this project to help members perform expansion planning studies and design economical, efficient, reliable, and robust transmission systems.

2012 Products

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<tr>
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<th>Product Type</th>
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<tbody>
<tr>
<td>Fast Fault Screening (FFS) and Potential Cascading Modes Selection</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</tbody>
</table>

P40.018 Protection System Simulator (070597)

Key Research Question

This project will be a continuation of Project P40.018 from 2011. The goal of the 2011 project is to determine the feasibility of creating a software-based (EMTP-RV) time-domain system protection simulator that is capable of providing results comparable to more costly hardware-based solutions, that is, a real-time simulators (RTS). In 2012, the model validation process will be initiated, and the library of P&C components will be expanded to include additional microprocessor-based relays. This work is unique in that, to date, time-domain simulation of P&C systems using detailed models has not been performed using a software-only solution. In the past, this type of simulation work has been accomplished using actual P&C hardware in conjunction with digital simulation equipment, the so-called "hardware in the loop" technique.

Approach

The developed simulation tool will be validated using results from an RTS. The purpose of the comparison is to validate the P&C models that will be developed, and in particular the protective relay models. The validation will be performed by comparing simulation results from an example system that is simulated using the proposed models and an RTS. Modifications to the models will be made where necessary. Once the simulation tools are validated, additional microprocessor based relay models may be developed to enhance the tool’s library of P&C devices. The number of additional relay models included in the project will be determined based on project participation. The findings and results of the validation process will be documented, and a detailed description of any additional relay models will be provided.

Impact

Modern computing technology has made it possible to simulate large systems in the time domain that can be of great benefit in some cases. In particular, having the capability of simulating system protection systems in the time domain enhances the industry’s ability to determine beforehand whether certain operating conditions or situations can or will negatively impact system reliability. Performing such analyses is paramount in evaluating system protection schemes, for example, special protection schemes defined by NERC before they are commissioned or performing post analysis of system events. Having the capability of performing simulations in software as opposed to using an RTS can translate into significant cost savings for a utility.

How to Apply Results

The detailed time-domain models that will be developed as a part of this project can be used by system protection engineers to evaluate protection schemes before they are commissioned, and perform post analysis of system events.
2012 Products

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<tbody>
<tr>
<td><strong>Protection System Simulator:</strong> Technical Update will document findings and results of the validation process as well as any additional relay models that are developed. Such documentation will allow a user of the simulation tool to be aware of the process that was used to validate the tool, as well as the details of any additional relay models that may be developed during the second phase of this project.</td>
<td>10/01/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Protection System Simulator Training Course:</strong> A multi-day workshop on the use of the developed protection system simulator. The &quot;hands-on&quot; work shop will provide engineers with in-depth training on simulating protection systems in the time domain using the developed simulation tool. Training will allow users to become proficient with the simulation tool much faster than through self-study alone.</td>
<td>11/01/12</td>
<td>Workshop, Training, or Conference</td>
</tr>
</tbody>
</table>

P40.019 Strategic and Flexible Transmission Planning (070598)

**Key Research Question**

Transmission planning aims to ensure adequate reliability while minimizing expected costs to the consumer. This happens in the context of increased uncertainty, with regard to fuel mix, location of resources, plant retirement, and increased variability caused by wind and solar generation. In planning future systems, these uncertainties need to be taken into account to ensure robust plans that can adapt to different possible outcomes. The current planning processes perform an economic evaluation of a proposed project as a separate step following the reliability assessment. An integrated framework would consider both together and allow more prudent decisions.

Flexibility—the ability of the system to respond to changes in demand—has recently attracted attention primarily because of the increase in variable generation (VG). System planning will increasingly need to consider operational issues to ensure that sufficient resources exist to meet changes in demand (net of VG). In addition, resource and transmission planning are becoming more intertwined as location of resources becomes important. By properly quantifying the needs and sources of flexibility for a system, this need for flexibility can be included into the planning process. In systems with high degrees of variability and uncertainty, flexibility will be important both to meet reliability targets in terms of responding to changes in net load and to reduce the cost impacts of integrating large amounts of variable generation; more flexible systems should reduce the impacts of VG. This should be balanced against the fact that flexible resources tend to be more expensive. In addition, new sources of flexibility, such as demand response, are not well understood in terms of what they offer a system.

**Approach**

This project will continue work done in 2011 in P40.019 in two related areas. The first is transmission planning, which considers both economic and reliability aspects in one process and the evaluation of system flexibility to respond to increased ramps in demand caused by an increase in variable generation. The framework developed in 2011 to perform the balancing of reliability and economics in transmission planning (using value-based planning principles) will be developed into a software tool that will allow planners to make more optimal decisions.

The second part will complete the work in measuring flexibility, building on 2011 work. This will include ensuring that transmission is considered in measuring flexibility adequacy and the ability of newer resources such as demand response and storage to offer flexibility. Flexibility metrics will be proposed so that they can be adopted by bodies such as NERC to ensure flexibility adequacy in systems aiming for high penetrations of VG. Case studies will be extended from 2011 work to show the need (or otherwise) of such a metric; it is likely that an initial screening tool will be developed, if needed, to investigate whether a given region needs a more detailed...
analysis (by simulation of operation) to determine whether it has sufficient flexibility. This more detailed analysis would then include analysis of operational issues to quantify flexibility in the system. Particular focus will be paid to the consideration of demand response in planning for flexibility.

**Impact**

This project will provide numerous benefits to the development of the power system. In particular, it should allow better planning decisions to be made about transmission buildout and how best to use transmission and generation resources to maximize the value of flexible resources on the grid. The key benefits will include:

- A tool to allow planners to make prudent decisions that balance reliability and economics when building transmission
- Metrics to determine the flexibility needs and resources in a system, considering new and existing flexibility resources as well as the transmission network in a system
- Results from case studies that show the need to consider balancing reliability and economics and improvements that can be made by using the framework developed
- Identification of the proper consideration of flexibility in system resource planning by using case studies to show the value of flexibility

**How to Apply Results**

Building on the 2011 report, 2012 work will provide information for members to start applying the methodologies developed in their own planning process. By properly considering flexibility, as opposed to capacity, adequacy in their system planning, planners should be able to make more optimal decisions about transmission project location and justification. Existing planning tools can be altered using the proposed framework to consider reliability and economics incorporated into the planning process together with metrics on flexibility needs and sources.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td><strong>Balancing reliability and economics in transmission planning</strong>: This tool will be developed so that a planner can make prudent planning decisions by following the framework developed with regard to reliability and economic justification of a proposed project.</td>
<td></td>
<td>Software</td>
</tr>
<tr>
<td><strong>Metrics and methods for consideration of flexibility in power system planning</strong>: This report will document proposed metrics and methods to measure flexibility, giving detailed case study examples, with a particular consideration of how new sources of flexibility such as demand response can be considered as a flexibility and capacity resource.</td>
<td></td>
<td>Technical Report</td>
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</table>

**P40.020 Frequency Response Adequacy (072028)**

**Key Research Question**

The issue of interconnected power system response to large generation and load unbalance (for example, that caused by the loss of generation) is an important one. Adequate generation reserve, inertial response, and primary frequency control are needed to ensure that the interconnected power system properly recovers from major frequency disturbances. Recent reports [1] have clearly documented both the apparent recent decline in primary frequency response in the North American power system and concerns over maintaining adequate frequency control. A recent Federal Energy Regulatory Commission (FERC) sponsored report [2] further emphasizes the need for establishing clear metrics for assessing frequency response adequacy. With this background, this project intends to look at these issues in detail, propose metrics for the measurement of
frequency response, and provide technical insight into the discussion of frequency response adequacy at the reliability level.


**Approach**

The project approach is to first take a close look at frequency response metrics, that is, how we assess the frequency response of a power system and how we can effectively measure it. The next step is to take an example system and, through the development of a step-by-step study approach, look at the frequency response of the system and identify the factors that affect adequacy.

**Impact**

The benefit of this work is that it will help to inform the frequency response initiative of NERC and thus help to bring more technical input into the industrywide dialogue on this important subject.

**How to Apply Results**

Our goal is to coordinate this work closely with that of NERC and other stakeholders to bring technical value to the industrywide discussion on this important issue. The application of the result would publicly disseminate the learning to inform regulators and decision makers.

The project technical report can be used as a reference to analyze system events in order to assess the frequency response of the bulk power system and to identify resources requirements (for example, operating reserves) for adequate primary and secondary frequency responses.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Frequency Response Adequacy</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</tbody>
</table>
Supplemental Projects

Advancing Bulk System Reliability Assessment of Smart Grid Operations (072030)

Background, Objectives, and New Learnings
The relationship between Smart Grid deployment and the reliability of the power delivery system is complex, involving interactions at many different levels of the system. A particular concern is gauging the cumulative influence that distribution-level adoption of Smart Grid technologies might have on the bulk system. Although smarter distribution systems have the potential to dramatically improve reliability, relying on widely distributed devices, communication devices, and control structures could have unforeseen implications for the adequacy and security of the overall grid. Because Smart Grid deployment is progressing at a rapid pace—with many facets already being implemented by several utilities and customers—there is an increasing need to account for these potential reliability concerns.

Knowledge gained during this research will provide an understanding of the degree to which distribution system characteristics and subsequently bulk power system reliability might be influenced by various Smart Grid operations. Key characteristics and potential reliability impacts of individual technology types as well as technology combinations will be examined based on projected portfolios occurring across different operating territories. Furthermore, Smart Grid operations designed to actively influence reliability (for example, providing bulk system ancillary services) will be evaluated along with inherent changes to distribution system characteristics. These findings will be used to advance analysis methodologies, system models, and metrics needed to effectively gauge system reliability given various Smart Grid deployments. The collaborative research will leverage expertise within EPRI, participating utilities, and other experts in the Smart Grid area.

Project Approach and Summary
This project seeks to understand how distribution system adoption of Smart Grid technologies might influence bulk system reliability as well as advance planning tools needed to effectively gauge system reliability under the resulting system changes. Specific objectives include:

- To identify Smart Grid technology attributes, interactions, and operations that might impact system reliability through technology evaluations
- To develop analysis methods, models, and metrics to quantify potential reliability impacts
- To perform reliability case studies using Smart Grid portfolio projections and host utility system data
- To increase the understanding of potential benefits, impacts, and operational sensitivities
- To develop general conclusions through the analysis of collaborative results

Benefits
A smarter, more sophisticated electrical system can provide many benefits to both utilities and customers. Full realization of these benefits requires understanding and evaluating system performance in the context of changing technologies and system improvements. Potential benefits of this research include:

- Better planning and coordination, resulting in more reliable customer service and efficient system operation
- Earlier realization of Smart Grid benefits through faster adoption and implementation of Smart Grid operations
- Development of tools necessary for effective utility planning and operation under changing system conditions
- Increased understanding of emerging technology performance and system interactions through collaborative research
Users Group for the Power Plant Parameter Derivation (PPPD) Software Tool (069917)

Background, Objectives, and New Learnings
For more than a decade, the U.S. Western Electricity Coordinating Council (WECC) has required that all generating stations be periodically tested for model validation. Similar model validation requirements are going to be put in place nationwide by NERC. After several years of R&D, EPRI has developed a Power Plant Parameter Derivation (PPPD) software tool. This tool has been used successfully to illustrate automated parameter fitting and model validation through two approaches: using staged test measurement data and using data recorded on-line from disturbance monitors (for example, digital fault recorders in the plant). This users group has the objective of being a forum for utilities that intend on using the tool to share learning and to better understand the tool’s application for meeting WECC and NERC requirements for generator model validation.

Project Approach and Summary
This project will focus on holding group webcasts and one annual face-to-face meeting. These forums will be an ideal setting for the following:

- To discuss enhancements and develop additional model requirements to be added to the tool
- To maintain the software and release future versions of the tool with new models (“bug fixes”)
- To share experience of various users with the tool
- To provide further training sessions

Benefits
This tool has two key values:

- It provides an automated algorithm to assist the engineer in the model validation process, significantly reducing engineering time.
- It provides a way to use on-line recorded data for model revalidation on a routine basis, eliminating the need to take units off-line for staged model validation testing.

A detailed explanation of the project and benefits of the work completed can be found in the 2009 base fund R&D project report.

This project will provide a forum to help utilities with the application of PPPD through workshops, users group meetings, webcasts, and software support. It also provides a way to continue to enhance the tool by adding more models or features to it, as appropriate.
Efficient Transmission Systems - Program 172

Program Overview

Program Description
This program has been developed to help utilities prepare for operating a power delivery system in a low-carbon future and deal with related impacts on system operation, maintenance, and planning. Key research and development (R&D) activities include assessing the costs, benefits, and performance of technologies capable of reducing power delivery losses and increasing efficiency.

The first few years the program increased the understanding of distribution efficiency through its Green Circuits Initiative, demonstrating technologies and practices that may increase efficiency along the feeder and changes in operations that may impact end-use efficiency. This research has matured and is now reintegrated with the Distribution Research program. For 2012, this program focuses on demonstrating increased transmission efficiency and utilization.

Research Value
With the knowledge acquired through this research program, program members will have access to information that can help them accomplish the following:

- Provide a framework for loss reduction and utilization increase on transmission systems
- Evaluate possible financial savings for utilities and improve the life expectancy of equipment
- Defer capital costs associated with new transmission construction
- Compare the economics of other efficiency options with increased efficiency in transmission
- Demonstrate a commitment to environmental issues through more efficient use of transmission resources

Provide a possible contribution to utility carbon dioxide (CO2) emission reductions and the overall greenhouse gas footprint

Approach
This program will analyze and develop strategies for balancing increased utilization and efficiency in transmission operations and may create a framework for comparing the various options for achieving higher utilization and efficiency. Options may include engineering solutions such as adoption of highly efficient equipment, line designs for reducing magnetic and electric effects, and operating lines at higher voltages. Operational solutions may include optimally managing the voltage profile on the grid, adjusting dispatch, and actively controlling the power flow using power electronics–based transmission controllers. This program will also look at assessing options to reduce auxiliary loads in substations.

The aim of the ARP is to provide the framework and analysis for understanding transmission efficiency options. Demonstrating the technologies for increased efficiency and utilization is the objective of supplemental projects hosted by various transmission owners and independent service operators (ISOs), sharing the results of applying specific technology options on their systems. In some projects, EPRI may be the lead investigator; in others, EPRI may simply apply the common framework, document the findings, and transfer them to members.

Accomplishments
In the past, the Efficient Transmission Systems program has delivered valuable information that has helped its members and the industry in numerous ways. Some examples include:

- Transmission Efficiency Technology Assessment: EPRI has not found an industrywide strategy for reducing transmission line losses. Some utilities are studying line losses, while others are investigating lower losses in large power transformers. Still other groups are focused on more efficient distribution
transformers. This report is an effort to determine which loss-reduction programs are in place, which strategies are in use, and how these strategies are being applied.

Current Year Activities
In the coming year, this research program expects to accomplish these objectives:

- Provide a framework for balancing transmission efficiency and utilization
- Document the finding of various technology and methodology demonstrations to increase efficiency and utilization in transmission

Estimated 2012 Program Funding
$1.0M

Program Manager
Richard Lordan, 650-855-2435, rilordan@epri.com

Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P172.001</td>
<td>Transmission System Loss Evaluation, Reduction: Technical and Economic Assessment</td>
<td>This project builds on the work initiated in 2008 through 2011 and provides objective investigation, analysis, and strategic measures to reduce losses on transmission systems and equipment. Numerous supplemental projects are underway to apply the approaches identified in the program. Results of the applications will be fed back into the framework to validate and refine the methodology.</td>
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P172.001 Transmission System Loss Evaluation, Reduction: Technical and Economic Assessment (065414)

Key Research Question
Utilities need strategic and objective information on loss evaluation for reducing transmission system losses as well as equipment using technology-based solutions. Implementing such solutions to reduce transmission losses requires utilities to study and assess not only the technologies, but also their transmission systems. Utilities need a comprehensive evaluation methodology and strategic planning framework to accomplish this task. Indeed, transmission companies are realizing the need for a consistent, analytical framework to evaluate the most cost-effective measures for achieving a specified reduced-losses goal or mandate. In addition, measurement and verification (M&V) procedures are needed after implementation to confirm that the anticipated improvements in losses are achieved.

Approach
This project provides a framework for assessing measures to reduce losses on transmission systems and equipment by developing industry-accepted methods for evaluating transmission losses by:

- Comparing transmission loss study approaches used by transmission companies and regional transmission organizations
- Developing a transmission efficiency accounting methodology
- Thoroughly validating the framework and methodologies using the information from supplemental demonstration projects to improve efficiency and utilization
The project assesses possible technical and economic impacts when implementing the following approaches and technologies to reduce losses in transmission systems and equipment.

**System Loss Reduction Approaches**
- Optimizing voltage profiles in systems, particularly during heavy load conditions, to reduce losses by using optimally located shunt capacitors/reactors, series capacitors/reactors, and secondary voltage regulation on generators to maintain higher voltage profiles at key transmission nodes.
- Using reactive power management—for example, improving load power factor and placing dynamically controlled reactive power sources such as static volt-ampere-reactive compensators (SVCs) and static synchronous compensators (STATCOMs) at large load centers remote from generation. These dynamically controlled reactive power compensators could be designed to meet the dual objectives of improving voltage instability and reducing losses in transmission systems and equipment.
- Using power electronics–based transmission controllers for active power flow control to reduce losses on transmission corridors.
- Using power flow analysis techniques to optimize voltage schedules, transmission substation transformer taps, and taps on phase-shifting transformers to minimize losses.
- Evaluating the potential for reducing losses by eliminating congestion, upgrading to higher line voltages, and locating various generation asset types closer to the load.

**Component Loss Reduction Approaches**
- Evaluating the potential of replacing existing conductors with high-temperature, low-sag (HTLS) conductors to reduce transmission losses.
- Evaluating low-loss substations. This will include both new and existing substations. LEED certification and its benefits, requirements, and guidelines will be explored.
- Evaluating efficient transformers will be explored.

**Approaches to Increase Utilization to Access More Efficient Generation**
- Evaluating dynamic ratings to increase line utilization to access a cleaner generation mix.
- Applying advanced power electric controllers and other smart transmission techniques to reduce congestion will be explored.

**Impact**
This project's results will benefit members in several ways:

- They will provide an understanding of the economic and technical benefits for implementing practical ways to reduce losses in transmission systems and equipment.
- Members will have a consistent methodology for determining transmission system losses, which would help them target cost-effective approaches for reducing system losses. It would also allow members to document those energy savings so that they can be properly credited toward energy-efficiency and carbon-reduction goals.
- Various loss reduction methods result in increased power transfer capability, which may be applied to defer the installation of new transmission facilities or relieve some constraints. Increasing loading of existing transmission facilities may result in incremental losses. Thus, a conflict between reducing losses versus increasing transfer capability may arise when these methods are implemented. The evaluation framework provides guidelines to properly address loss reduction techniques without conflicting with expansion planning and incremental transmission upgrades objectives.

Improved transmission system efficiency results in additional rewards for a transmission utility that implements measures to improve transmission system efficiency:

- It demonstrates an environmental commitment to regulators and the general public through the more efficient use of transmission resources.
- It reduces utility CO₂ emissions and a company's overall greenhouse gas footprint.
• It reduces electrical losses, resulting in financial savings and improved life expectancy of some equipment.
• It supports regulatory actions related to energy-efficiency mandates.

How to Apply Results

Project results and products comprise tools and guidelines that are designed to be used by engineers and managers for assessing and implementing measures to improve transmission system efficiency. In particular:

• Transmission engineers can use the knowledge contained in the project findings and products to develop methods for loss reduction, support transmission planning, respond to regulatory and other outside stakeholder inquiries, evaluate available technologies, perform trade-off analysis of competing projects, and inform senior management on technologies that could affect business operations.
• Planning engineers will use the framework as a guideline to assess projects for reducing transmission losses.
• Planners, along with other engineering departments, can use the framework as a basis for developing tailored methodologies and procedures for loss-reduction project evaluation and implementation and to respond to company-specific needs.
• Managers can use project results to implement M&V procedures to test and account for the anticipated improvements in transmission system efficiency.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Framework for Transmission Efficiency and Utilization</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
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</table>
Bulk Power System Integration of Variable Generation - Program 173

Program Overview

Program Description

Several ongoing environmentally driven regulatory issues—such as greenhouse gas reductions and associated CO₂ reduction initiatives as well as state-mandated renewable energy standards—along with improved economic viability for wind generation have resulted in the increased implementation of renewable energy. Much of the estimated development of renewables comprises variable resources such as wind generation and solar photovoltaic (PV), which, when integrated with the grid, create many new challenges for maintaining reliable system operation. Future projections are that a more significant build-out of these variable renewable resources is likely.

With these developments, power system planners and operators require new tools and resources to ensure a reliable, secure, and cost-effective supply of electricity to consumers. The new tools include improved and/or new sources of system flexibility to respond to and accommodate the increase in energy variability and uncertainty, the development of additional transmission infrastructure to deliver energy from remote locations, and planning and operational methods and software to effectively build and use these new resources.

Research Value

The mission of EPRI's Bulk System Variable Generation (VG) Integration research program is to provide variable generation scenario integration analytics; development of planning methods, tools, and models; and development of operator methods and tools to reliably and economically integrate wind and solar PV generation. In 2012, EPRI's Bulk System VG Integration research program will offer its members a focused research portfolio with the following objectives:

- Develop methods and tools to support risk-based transmission planning that integrates the uncertainty of variable generation and controllable loads when evaluating system facility requirements
- Develop methods and tools to determine operating reserve requirements for high levels of variable generation with consideration of all other system uncertainties
- Specify the requirements for operational tools and methods to support dispatch and supply surplus/deficiency decisions for high levels of variable generation
- Develop tools and methods to design and build a portfolio of supply and demand resources that provide sufficient capacity and flexibility to ensure a reliable and economic supply of energy
- Characterize the variability and uncertainty of solar PV and the resulting impacts on system operations
- Determine the impacts of increased system variability on the conventional generation fleet that must increase cycling duties to accommodate
- Develop and validate wind generation, solar PV, and other emerging flexible resource dynamic models for system planning studies

Approach

EPRI's Bulk System VG Integration research program delivers value by using the shared experiences and understanding of our utility and independent service operator (ISO) members in conjunction with the expertise of EPRI's staff and network of top-level contractors to conduct research projects that lead to actual methods and tools used by system planners and operators responding to the challenges of high penetrations of VG.

EPRI also engages with external industry standards, regulatory, and research efforts to ensure that the EPRI research program is taking advantage of broader industry efforts and advancing the state of the art. For example, EPRI staff serves on the leadership group of the North American Electric Reliability Corporation (NERC) Integrating Variable Generation Task Force, ensuring that member perspectives are incorporated into the activities of such groups and that EPRI research is designed to help members respond to the requirements
that emerge from such efforts. Our research program also strives to give members both short- and long-term value. For example, the 2012 Bulk System VG Integration research program will continue efforts to validate existing generic wind generation dynamic models that are being used for interconnection and planning studies today while conducting research to develop operator tools that will suggest generation re-dispatch and/or transmission network reconfiguration solutions to post-contingency or variability events.

Accomplishments

The Bulk Power System Integration of Variable Generation program was created in 2009. Program products and accomplishments in 2009 and 2010 include the following:

- Development of methods and tools to support risk-based transmission planning that integrates the uncertainty of variable generation and controllable loads when evaluating system facility requirements
- Development of methods and tools to determine operating reserve requirements for high levels of variable generation with consideration of all other system uncertainties
- Specification of the requirements for operational tools and methods to support dispatch and supply surplus/deficiency decisions for high levels of variable generation
- Development and validation of wind generation, solar PV, and other emerging flexible resource models for system planning studies
- Continued interaction and representation of member interests through the NERC Integration of Variable Generation Task Force (IVGTF) leadership team

Current Year Activities

In 2012, EPRI's Bulk System VG Integration research program will offer its members a focused research portfolio with the following objectives:

- Develop methods and tools to support risk-based transmission planning that integrates the uncertainty of variable generation and controllable loads when evaluating system facility requirements
- Develop methods and tools to determine operating reserve requirements for high levels of variable generation with consideration of all other system uncertainties
- Specify the requirements for operational tools and methods to support dispatch and supply surplus/deficiency decisions for high levels of variable generation
- Characterize the variability and uncertainty of solar PV and the resulting impacts on system operations
- Determine the impacts of increased system variability on the conventional generation fleet that must increase cycling duties to accommodate
- Develop and validate wind generation, solar PV, and other emerging flexible resource dynamic models for system planning studies

Estimated 2012 Program Funding

$1.5M

Program Manager

Daniel Brooks, 865-218-8040, dbrooks@epri.com
Summary of Projects

PS173A System Planning Methods, Tools, and Analytics (072093)

Project Set Description

P173 Project Set A focuses on the development of methods and tools for supporting resource adequacy and transmission planning for systems that must accommodate the variability and uncertainty of high levels of variable generation such as wind and solar PV. Planners for these systems need validated models of these new technologies and system planning/analysis platforms that use these models while representing the uncertainty of output from these variable resources over time. This project set includes research to provide these new models, tools, and methods.

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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P173.003</td>
<td>Grid Performance and Modeling of Variable Generation and Evolving Power System Resources</td>
<td>This project intends to develop a model validation tool for generic nonproprietary models for wind turbine generators.</td>
</tr>
<tr>
<td>P173.006</td>
<td>Advanced Planning Tools to Study the Impact of Variable Generation and Controllable Loads</td>
<td>This project develops methods and tools that allow transmission planners to incorporate and consider the added uncertainty when evaluating system reliability and facility upgrades that will be required to support future generation and load requirements.</td>
</tr>
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</table>

P173.003 Grid Performance and Modeling of Variable Generation and Evolving Power System Resources (067489)

Key Research Question

Many states have already passed renewable energy requirements, and there is still the prospect for a federal requirement. Many of these requirements include specific targets for wind and solar generation. As a result, there is an increasing effort to develop bulk system interconnected wind and central solar PV plants and integrate solar PV panels in residential and commercial constructions. When connected to the distribution system in sufficient quantities, PV generation is capable of impacting power grid behavior during system disturbances. It is important to understand the characteristics of wind and solar PV generation as well as other emerging resources, whether bulk system interconnected or distributed, with respect to the way in which these devices respond to voltage and frequency variations in the power grid.

In 2011, EPRI is working in collaboration with Western Electricity Coordinating Council (WECC), International Electrotechnical Commission (IEC), Institute of Electrical and Electronics Engineers (IEEE), and other industry groups to continue to develop generic, nonproprietary wind turbine generator models and solar PV models. In addition, we are working on acquiring measurement data for wind turbine generator and wind power plants to prove the concept of model validation for the generic models using measured disturbance data. Assuming that these efforts will be successful in 2011, the intent in 2012 is to move toward the development of a software tool for model parameter estimation and validation for wind plants, similar to EPRI Power Plant Parameter Derivation (PPPD) software for synchronous generators.

Approach

This effort will build on work begun in 2010 that involved working with industry groups to develop and validate generic wind generation dynamic models and solar PV dynamic models. It is anticipated that in 2011 the project will provide for completing PV model development and the validation and development of generic wind turbine generator models.
Assuming that we have been able to achieve the intended goal of proving the concept of wind turbine generator model validation using on-line measured disturbance data, in 2012 the key goals are as follows:

1. **Software Tool Development.** This is focused on developing the algorithms and models developed and tested in 2011 into a stand-alone software tool for model validation of generic wind turbine generator models using measurement data. The tool will be developed in MATLAB® and compiled into a stand-alone tool using the MATLAB® Complier. The models implemented will be the generic models developed through the WECC Renewable Energy Modeling Task Force and IEC TC88 WG27 efforts.

2. **Software Release.** We will release the model to the public through www.epri.com.

**Impact**

The benefit of this work is the public dissemination of a tool to facilitate the validation of generic wind turbine models.

**How to Apply Results**

Various forums such as webcasts will be used to demonstrate the usage of the developed software tool. In addition, a workshop or tutorial could be organized for training users in the application of the tool, but this would need to be done after the tool is developed and released and so may be scheduled in 2013.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Wind Plant Parameter Derivation Software Tool: This software tool is a stand-alone software tool for model validation of generic wind turbine generator models using measurement data. The tool will be developed in MATLAB® and compiled into a stand alone tool using the MATLAB® Complier. The models implemented will be the generic models developed through the WECC Renewable Energy Modeling Task Force and IEC TC88 WG27 efforts.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
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</table>

**P173.006 Advanced Planning Tools to Study the Impact of Variable Generation and Controllable Loads (069256)**

**Key Research Question**

Global climate concerns are influencing the ever-increasing role that renewable and variable generation will play as future energy sources. At the same time, interest in the smart grid has accelerated in the United States and the rest of the world, with smart meters connected to customers with controllable loads likely leading the way for smart grid deployments. The proliferation of high levels of variable generation and controllable loads will require grid planners to incorporate much higher levels of uncertainty in their models to adequately represent the many potential system scenarios that might result. These models will be necessary to maintain grid reliability and reduce system development and operating costs.

Research is needed to develop advanced risk-based planning tools that integrate the planning and operation of customer demand, energy storage, and renewable generation. In the absence of such tools, system operators are more likely to be required to operate in system configurations and scenarios that might not have been adequately studied in the system planning. Or, transmission planners might take a conservative approach in planning to ensure that sufficient margin exists to cover unstudied configuration and scenarios, resulting in inefficient infrastructure upgrades and overbuilt capacity. System planners need to properly evaluate transmission capacity requirements and grid reliability when higher levels of variable generation and controllable loads are anticipated.
**Approach**

The objective of this project in 2012 is to develop prototype software based on EPRI’s TransCARE and to prepare a functional specification for other planning software to incorporate the probabilistic models developed in 2011. This tool and methodology could be used for transmission planning with large amounts of VG. The benefit of this tool is that a more economic transmission plan can be produced while maintaining reliability at a desired level, without the need for exhaustive, costly time simulations of every feasible state.

- Model the uncertainties associated with renewables, including wind and solar. Usually, wind farms and solar collection points are combined or treated as a single entity in steady-state power flow models; such simplifications result in low-accuracy simulation. A rigorous probabilistic mathematical model will be developed to capture variations of renewable generation and take into account the correlation of these variable generations with system loads. This work will incorporate research results by EPRI and others on modeling the intermittent nature of renewable generation.

- Develop system load shapes and load factors with various assumptions of penetration scenarios of controllable loads, before and after applying control. EPRI will also identify ways that controllable loads can be used as control variables that can decrease or increase at various points in a bulk power transmission system.

Develop advanced planning tools to perform reliability assessments for comparing alternative transmission expansion plans to accommodate a high penetration of renewables and controllable loads. EPRI will implement the developed model on existing probabilistic and risk-based transmission planning tools (such as TRELSS/TransCARE—enumerative procedure based).

**Impact**

Transmission planners are tasked with efficiently building a grid that operators can reliably operate. Increased uncertainty in generation dispatch patterns and load patterns increases the complexity of the planners’ problem. This project develops methods and tools that allow transmission planners to incorporate and consider that added uncertainty when evaluating system reliability and facility upgrades that will be required to support future generation and load requirements. By explicitly representing the uncertainties related to variable generation and controllable loads, planners will be able to more efficiently plan system upgrades and avoid intentional overbuild solely for the purpose of providing planning margins to cover these known uncertainties.

**How to Apply Results**

The project's products will help members understand how to conduct advanced planning for the entire power supply and delivery chain. Members will be able to use the best available data and information about load composition and load models that recognize all resources and demands. Typical system load shapes will be available for members to use for system studies. The tools and methods developed can be integrated into members’ planning procedures to ensure that the uncertainty associated with variable generation and demand response is rigorously represented. Webcasts will be held regularly to engage members in research efforts and facilitate information sharing.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</table>
PS173B System Operations Methods, Tools, and Analytics (072095)

Project Set Description

P173 Project Set B focuses on the development of methods and tools for supporting operational planning and real-time operations for systems that must accommodate the variability and uncertainty of high levels of variable generation such as wind and solar PV. Schedulers and operators for these systems need new visualization and dispatch support tools to economically and reliably commit and dispatch generation and to reconfigure the transmission network in response to the increased regulation, load following, and cycling required to respond to the variability of VG over time. This project set includes research to provide these new models, tools, and methods.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P173.005</td>
<td>Operator Tools for Scheduling, Reserve Determination, and Frequency Control with Variable Generation</td>
<td>This project will develop methods and tools that allow operators to more reliably and efficiently schedule resources to meet demand while maintaining adequate reserves in the operational planning timeframe and to provide dispatch decision support and methods for improved frequency control in real-time operations.</td>
</tr>
<tr>
<td>P173.007</td>
<td>Bulk Electricity System Impacts of Distributed and Transmission System Connected Solar PV</td>
<td>This project will evaluate the integration of solar PV, both as a comparison with the integration of wind and by assessing potential adverse impacts of high levels of PV on bulk system reliability as well as provide guidelines for mitigating such negative impacts.</td>
</tr>
<tr>
<td>P173.008</td>
<td>System Operational/Planning Impacts of Cycling</td>
<td>This project will develop methods to better understand the range of operating and planning impacts of increased generator cycling resulting from variable generation and propose mitigating strategies to reduce those impacts.</td>
</tr>
</tbody>
</table>

P173.005 Operator Tools for Scheduling, Reserve Determination, and Frequency Control with Variable Generation (069255)

Key Research Question

The variability and uncertainty associated with variable renewable generation such as wind and solar PV can have a significant impact on system performance and market operation as penetration levels increase. Specifically, the variability and uncertainty make it much more challenging for system operators to schedule the most economical set of resources to meet system requirements, determine operating reserve requirements to ensure reliability, and maintain real-time frequency and voltage performance to established standards. Consequently, new operational scheduling and control methods and tools are needed to ensure reliable system operation in the most efficient and economical manner. A stochastic optimal power flow (OPF) application has been developed; this improves generator scheduling and reserve determination by including the stochastic nature of wind and load when scheduling a system. This type of application results in a schedule that is more robust to changes in wind and load and reduces total expected costs. In 2012, EPRI will continue to develop the stochastic OPF Reserve Determination and Rapid Redispatch applications documented in 2011 on a realistic scaled system.

Approach

EPRI will continue work begun in 2010 and continued in 2011 to develop two operations applications—Reserve Validation and Rapid Redispatch—that can assess existing reserve schedules to ensure that they are adequate and rapidly determine optimal dispatches to respond to random forecast errors and contingencies.

Emphasis will be on integrating these applications into prototype tools at scale so that they can be used on operators’ and schedulers’ desks. EPRI will collaborate with commercial EMS vendors to ensure that tool
prototyping is coordinated in a way that allows the results to be used by vendors in developing commercial tools that integrate with utility and ISO EMS products.

**Impact**

- Power system operators and planners will have new capabilities to optimally schedule generation to meet demand and determine reserve requirements that balance the introduction of emerging energy resources with system reliability.
- This project will offer system operators insights into the potential impacts of variable generation on frequency control as well as new methods for minimizing any negative impacts on system frequency performance.

**How to Apply Results**

- EPRI will provide project status updates and training webcasts to communicate the strengths and applications of the developed operator tools and methods.
- Participants will read the technical report and implement recommendations for Reserve Validation and Rapid Redispatch applications.
- Participants will work with associated vendors to develop and test developed prototype tools or modified system algorithms.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Application of STOPF to Reserve Validation and Rapid Redispatch of System Operations:</strong> The report is designed to help members realize the benefits of this technology in their own business processes. Members can utilize this report to create specifications for implementing Reserve Determination and Rapid Redispatch applications by preferred vendors. The report will include and reference useful case studies that can help verify implementations.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>

**P173.007 Bulk Electricity System Impacts of Distributed and Transmission System Connected Solar PV (070599)**

**Key Research Question**

Solar PV is expected to make a significant contribution to generating capacity in the next decade. Similar to wind power, it has characteristics of variability and uncertainty in its output and is non-synchronous to the electrical grid. Because much work has already been done regarding the integration of large amounts of wind, there is a large body of knowledge that can be used to ease the integration of solar PV. Although it is expected that the impact of solar PV in terms of reliability, economics, and effect on the balance of the system will be similar to that of wind, there will be some differences. This project will quantify the differences between wind and solar PV from a bulk system point of view as well as the impacts of these differences on planning and operational procedures.

In addition, PV is likely to be connected on the distribution network. This will create challenges in assessing the impact of solar PV. For example, lack of low-voltage ride-through might result in large amounts of solar PV dropping off when there is a fault on the transmission network, resulting in further deterioration of the voltage. There is also the possibility that, rather than impacting negatively on reliability, the PV inverter could be used to improve system reliability. Therefore, the impacts of distributed PV on bulk system operation need to be assessed and mitigating strategies, possibly using the inverter, proposed.
Approach

Building on work done in P173.007 in 2011, the impact of solar PV on reliability will be further extended. Work in 2011 will examine the impact of low-voltage ride-through capabilities (or lack thereof) on the BES. Work in 2012 will extend this to more detailed case studies, examining various scenarios showing the potential benefits that various inverter capabilities (such as volt-var control) can bring. Other reliability impacts, such as under-frequency load shedding issues or reactive power provision, can be addressed. The project team will work closely with related EPRI projects being conducted to assess the impacts of smart grid developments on system reliability.

In addition, the variability and uncertainty impacts of PV will be examined using similar production cost tools to those used in wind integration studies to quantify the difference in impact between solar PV and wind. High-resolution (temporally and spatially) data will be used to quantify the variability of the PV resource on an aggregated system. A key aspect of this will be to understand the impact that the nature of PV, as a distribution network connected resource, will have from the point of view of its lack of visibility and controllability, and how that will impact reserve provision and generator scheduling. This work will be closely aligned with work done in the NERC IVGTF on bulk system impacts of distributed resources; it will also align with integration studies being done, by EPRI and others, for large amounts of PV on various networks.

Impact

This project will provide the analytical foundation and guidance for integrating large amounts of PV onto distribution and transmission networks. By using high-resolution data, several important aspects of PV integration can be assessed:

- From a bulk system point of view, the variability and uncertainty characteristics of PV will be quantified; these can then be compared to wind impacts to assess the key differences, in terms of provision of operating reserve, flexibility needs, and operation of conventional plants on a system with high PV penetration.
- The reliability impacts of distributed PV will be better understood so that they may be addressed. Examining multiple types of systems can illustrate the significance of system type to the scale of the impacts.
- The ability of the PV inverter to aid bulk system reliability will be assessed for various operating strategies.

How to Apply Results

The project’s analytical results and resulting operating and planning guidelines should be disseminated through each company’s operations, planning, and standards functions to ensure that appropriate processes are developed as solar PV becomes more broadly integrated. By using the comparisons between wind integration and solar PV integration, the best practices identified for wind integration can be adopted for solar PV integration. In addition, areas with low amounts of wind but high potential for solar PV can use results to better understand likely impacts on system operation and planning.

2012 Products

<table>
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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Bulk Electricity System Impacts of Distributed and Transmission System Connected Solar PV: This update will show the reliability impact of solar PV on distribution and transmission networks, and propose mitigating strategies, which have been evaluated on test systems. In addition, it will quantify the differences between the variability and uncertainty of wind and solar PV.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
P173.008 System Operational/Planning Impacts of Cycling (072094)

Key Research Question

With increasing levels of variable generation (VG) being added to the grid, cycling of conventional units will increase. Cycling, which in this context refers to starting and stopping a unit or ramping a unit frequently through its operating range, can have detrimental effects on the performance, lifetime, and efficiency of conventional thermal and hydro units. Of particular concern are generators originally designed to be baseloaded, but which will be required to act as a mid-merit or peaking plant when there is a large increase in low-cost, variable energy sources such as wind and solar PV. In addition, new requirements on conventional plants resulting from environmental regulations might reduce the flexibility and increase the costs of cycling for the existing generation fleet.

This project intends to use the work to quantify cycling costs being conducted by EPRI's Generation Sector to better understand the likely impact this cycling cost knowledge will have on existing planning and operational paradigms. This knowledge can then be used to propose new methods or tools to incorporate cycling costs into planning and operational procedures. This will ensure that the potential cycling cost and reliability implications are fully considered when optimizing commitment and dispatch decisions when high levels of VG exist.

Approach

This project will examine the operational and planning changes needed to account for unit cycling costs and/or unit loss of life. Cycling cost quantification will be used from other areas (for example, EPRI's Generation Sector) to understand the impact of these costs on planning and operating systems. For example, the increase in cycling expected of a particular type of unit will be used to develop an understanding of the likely impact this will have on costs, maintenance schedules, lifetime, outage rate, emissions, and other factors. This information can then be used as input to a generator scheduling algorithm to ensure that the overall system costs can be reduced over the course of one or multiple years. Different ways to include the various cycling impacts (for example, as dynamic start costs or changed forced outage rates) in scheduling systems will be developed and assessed to best mitigate the long-term effects of cycling.

Planning techniques will also need to account for unit cycling, and the knowledge of cycling impacts on the build-out of generating capacity will be examined. Optimal system planning will consider generator cycling and its long-term impact in terms of reduced lifetimes, need for retrofitting, and increased outage rates. In addition, the way VG is treated when operating the system will be examined—for example, priority dispatch rules and their effect will be analyzed. This work will likely use a production cost model to gain a fuller understanding of the way in which production costs and expected dispatches will change when cycling is considered. The results will be a quantitative description of the effects of cycling on the planning and operational timeframes for a system, together with proposed strategies to properly integrate the cycling impacts into operational and planning tools.

Impact

This work allows quantification of the impacts and assessment of mitigating approaches to unit cycling, with a particular focus on VG. Key benefits will include:

- Identification of the extent of additional damage caused by cycling wear and tear caused by additional VG and its impact on power system operation.
- Identification and assessment of various approaches to mitigate the various cycling effects that will be caused by VG.
- Development of a better understanding of the true costs and impacts of the integration of VG.
- Provision of input into decision-making processes for future plant mix and quantify the benefits of retrofitting existing plants to allow for increased cycling.
- Development of approaches to minimize long-term impacts of cycling in operational planning.
How to Apply Results

Results from this project will be of use when planning and operating systems, particularly those for which significant levels of VG are envisioned. Although the identification of cycling costs will allow them to be quantified, for these costs to be of most benefit they need to be considered as part of the entire system. This project will enable planners and operators to better understand the impacts of cycling and to consider possible methods for better reducing its impacts as part of the ultimate goal of minimizing systems costs while maintaining reliability at desired levels. These methods will need to consider both the short- and long-term time scales to enable better operation of the system while considering longer term planning needs.

2012 Products

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<tr>
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<th>Product Type</th>
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<tbody>
<tr>
<td>Impact of Generator Cycling Costs on Planning and Operation of Systems with High Variable Generation and Possible Mitigating Strategies: This update will provide an overview of the types of impacts increased cycling costs due to variable generation will have on system operation and planning; strategies to best incorporate and mitigate cycling into operational and planning procedures will be proposed and evaluated.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>
**Supplemental Projects**

**Field Demonstrations of Wind and Solar PV Plants Providing System Frequency Response and Regulation (072096)**

**Background, Objectives, and New Learnings**

Wind and solar PV generation has generally not been designed to supply inertia, primary frequency response (governor), or secondary frequency response (automatic generation control [AGC]) to the system. In systems in which large amounts of these variable resources have been installed, there are periods of time during which an increasing percentage of the load is served from these resources pushing more conventional generators, which typically supply these needed functions, off the system. As a result, studies of systems anticipating high wind and/or PV penetrations have shown potential stability concerns as penetrations increase if the renewable resources are not controlled in a way that provides some similar inertial and primary frequency response.

In response to these concerns, system planners and operators along with wind turbine manufacturers and plant owners/operators have begun to consider the extent to which wind plants might be able to provide these functions with some systems establishing requirements. In addition, some wind turbine generator (WTG) manufacturers have begun testing and deploying new control packages that allow the WTGs to emulate inertial response. To date, however, there has not been a succinct, focused effort for most North American systems to evaluate the levels at which systems might be beginning to have these potential stability issues and to evaluate the effectiveness of wind and solar PV plants to supply these needed reliability functions as they push conventional generation offline.

This project will provide for actual field verifications of the ability of wind generation and solar PV generation plants to adequately supply inertia, primary frequency, and AGC response when interconnected to the bulk power system. This work will give system operators a better understanding of the types of advanced controls that contribute to these required system functions.

**Project Approach and Summary**

EPRI will work with the National Renewable Energy Laboratory (NREL) to use its utility-scale test wind turbines to test various active power control schemes for contributing to system frequency responsive functions. EPRI will also pursue a partnership with a commercial wind plant that has implemented or is willing to implement a commercially available active power control package offered by the wind turbine manufacturer for the turbines used in the plant. For both the NREL test turbines and a commercial plant that will be potentially identified, EPRI will conduct measurement and verification (M&V) of the turbine/wind plant active power output during specific frequency disturbances that naturally occur on the interconnected power system.

EPRI will also work with the University of Texas at Austin (UT-Austin) to evaluate any relationships between online wind generation and the Electric Reliability Council of Texas, Inc. (ERCOT) system frequency responsiveness for disturbances in the ERCOT system. This evaluation will use synchrophasor data collected across the ERCOT system as part of a joint EPRI and UT-Austin synchrophasor network project.

**Benefits**

This project will give system operators and planners an understanding of the abilities of wind generation and solar PV generation to effectively contribute to the frequency responsive needs of the power system during disturbances and steady-state operation (AGC). The M&V effort will confirm whether emerging renewable resources can provide the functionality of the conventional generation that they might replace or whether there are limitations to the frequency responsiveness of wind and PV with advanced controls. If the effectiveness of these controls can be confirmed, one of the major concerns that have been voiced relative to the potential system reliability impacts of variable generation will be removed.
Impact of Renewable Energy Resources on System Protection (072097)

Background, Objectives, and New Learnings

The integration of renewable energy resources into the transmission grid presents significant technical challenges for system protection and planning engineers. The power electronics associated with some wind turbine generators (WTGs) and photovoltaic (PV) inverters can produce current waveform signatures that are significantly different from those of traditional synchronous or asynchronous generators. As such, traditional short-circuit modeling techniques do not accurately represent the behavior of renewable energy resources during short-circuit events. Accurate short-circuit models of renewable energy resources are not available; consequently, protection and system planning engineers are required to make judgments based on limited information about the behavior of these devices during short-circuit events. The primary objective of this research project is to evaluate the impact of renewable energy resources on system protection. New learning will result from an improved understanding of the way in which these devices affect system protection and of improved short-circuit models for system studies.

Project Approach and Summary

This multiphase project will address many of the technical issues faced by protection and planning engineers when analyzing systems with high-penetration renewable energy resources. Improved short-circuit models of various renewable energy resources will be developed to aid in performing system studies such as protection and coordination and circuit breaker duty. The performance of various instrument transformers (for example, current transformers, wound potential transformers, and capacitive coupled voltage transformers) when subjected to the unique waveform signatures of renewable energy resources will be evaluated, and the impact of renewable energy resources on the performance of protective relay hardware and settings will be explored.

Benefits

Utilities are under considerable pressure to increase the percentage of renewable energy resources in their generation fleet. The DOE has outlined a plan to increase the percentage of power generated in the U.S. from wind power to 20% by 2030, and large-scale PV integration will increase the percentage of renewable energy resources even higher. As the percentage of renewable energy resources increases, so will the likelihood of experiencing problems caused by the assumptions being made regarding the short-circuit behavior of renewable energy resources. This research will proactively address these issues before they become a hindrance to the long-term sustainability of high-penetration renewable energy resources.
Integration of Distributed Renewables - Program 174

Program Overview

Program Description
The integration of distributed renewable generation sources into the electricity grid poses a number of challenges for the electric industry. Utilities face a variety of generator sizes, connection points, and electronic interfaces including cases of relatively high penetration on existing distribution systems. This program addresses these challenges with projects that assess interface devices, analytics, system studies, monitoring, special applications, and maintenance for effective interconnection and integrated operation of distributed generation resources. The program includes lab and field evaluations and demonstrations of improved power control and communications. A primary objective is to expand utility hands-on knowledge and capability to use and monetize the value of renewable generation without reducing distribution safety, reliability, or asset utilization effectiveness.

Research Value
With the knowledge acquired through this research program, members will have access to information that support the following:

- Maintaining distribution network reliability and safety
- Strategies for responding to customer-sited renewable generation
- New business models, economic analysis of ownership options, and potential to rate-base distributed assets
- Proactive response to state and federal renewable portfolio standards (RPS)
- Planning for renewable deployment and advanced distribution automation
- Utilizing the value of the utility distribution system to support renewable distributed generation

Approach
This research program continues and builds on previous work related to distributed renewable resource integration coordinating with advanced distribution automation, efficient distribution circuits (Green Circuits), and the IntelliGrid research program, as well as smart grid demonstrations. A range of products are identified for each project. Participants’ input and prioritization will determine the final deliverable plan.

Accomplishments
The distributed integration program has delivered valuable information to members and industry. Over the past year the following information came out of the program:

- Standard Language Protocols for Photovoltaics and Storage Grid Integration (1020906) describes efforts underway to identify the basic inverter/charger capabilities and develop a standard communication protocol to support higher grid penetration levels of distributed assets.
- Addressing Solar Photovoltaic Operations and Maintenance Challenges (1021496) provides an overview of current operation and maintenance (O&M) practices and lessons learned based on experiences with grid-connected solar photovoltaic systems.
- Guideline on Voltage Control Strategies for High Penetration Distributed Generation (1020155) addresses advanced voltage control strategies for inverter-connected distributed generation, with an emphasis on solar photovoltaic generation.
- EPRI led an effort with key stakeholders to develop processes to create uniform standard functions for off-the-shelf inverter and communication products for utility systems and standards are beginning to appear as a result of this work.
Current Year Activities

- Develop screening tools, criteria, and guidelines for increasing penetration of renewable generation in existing radial and network distribution, as well as future circuit functional requirements
- Member's workshop to share current practices and identify future need for planning and integration tools, as well as assessment of advanced circuits design concepts
- Evaluate communication interfaces for distribute energy resources (DER) and advanced metering infrastructure (AMI) with inverters, includes development of performance criteria, lab and field testing
- Develop performance criteria, design, test to evaluate available intertie hardware, systems, and configurations
- Assess photovoltaic (PV) system installation, maintenance, and asset management issues and apply O&M knowledge and develop utility best practices
- Evaluate inverter failure modes and limits, develop accelerated life testing, and look at different configuration effects on output performance and reliability

Estimated 2012 Program Funding

$3.5M

Program Manager

Tom Key, 865-218-8082, smullapu@epri.com

Summary of Projects

PS174A Distribution Readiness for Integration of Renewable Generation (067431)

Project Set Description

This project set provides analysis of existing distribution issues and looks at future options and concepts that address higher penetration of PV generation, storage, and other distributed energy resources (DER). It focuses on the distribution system's readiness, both radial and network distribution, for incremental increases in distributed generation. The project set is aligned with the Electric Power Research Institute's (EPRi's) Green Circuits, Smart Grid, Electric Transportation, and IntelliGrid programs.

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P174.001</td>
<td>Planning and Analysis to Integrate Variable Resources into Distribution</td>
<td>Continues 2011 activities engaging utility personnel in applying screening tools, developing planning and application guidelines, and looking at new feeder designs and operating parameters for higher penetrations of distributed generation</td>
</tr>
</tbody>
</table>

P174.001 Planning and Analysis to Integrate Variable Resources into Distribution (067492)

Key Research Question

Most existing radial and network distribution systems are not designed for a significant penetration of distributed generation. Standards that address the interconnection of distributed generation (for example, IEEE 1547-2003) have assumed very low penetration levels. The industry recognizes that these requirements are changing with the significant deployment of distributed PV in many utility systems. This project set addresses the changing requirements in distribution planning and analysis. The main objective is to enable higher levels of distributed resource integration without jeopardizing safety, reliability, operational efficiency, and power quality. New learning is expected to come out of planning methods, analysis techniques, and sharing of field experiences.
Approach
This project looks at making incremental renewable generation additions in today’s existing radial and network distribution systems without sacrificing safety, reliability, or effectiveness. Design concepts and functional requirements for future distribution will be developed. Starting with prior EPRI research and development, this project focuses on changes needed in planning, design, and operating criteria for high penetration of distributed and variable generation resources. It will provide guidelines, impact analysis, and assessment methods to determine the limits and analyze the expansion options and potential system value. A range of products are identified for each project.

Impact
- Enhance ability to conduct resource planning, improve on interconnection screening and requirements, and maintain circuit performance and reliability
- Gain access to and exchange up-to-date information; share best practices, state-of-the-art developments, and related information from other distribution companies
- Benefit from collaborative R&D activities and sharing applications, experiences, lessons learned, and solutions related to integrating distributed renewable generation
- Address current renewable power generation issues via analytical studies, developing planning methods, applying screening tools, and evaluating specific interconnection case studies

How to Apply Results
Utilities faced with planning or integrating new renewable generation will utilize the results of this project to ensure that the full implications of safety, reliability, and electrical performance are considered. Findings can be used to work with developers wanting to connect green buildings, construct zero-energy homes, and implement sustainable community strategies.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td>Modeling High-Penetration PV for Distribution Interconnection Studies:</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Development of Engineering Guidelines for High-Penetration Scenarios (Initial Chapters for future EPRI Color Book document):</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Initiate process of developing recommended guidelines for advanced circuits needed to integrate higher levels of renewables and distributed generation and evolve into an EPRI Color Book. Develops recommended guidelines for resolving issues between bulk system reliability needs versus local feeder interconnection requirements for interconnection, voltage ride-through, protection, and voltage/var control. Proposed initial chapters:</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Overview of Impacts on Planning Tools</td>
<td></td>
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<tr>
<td>Communication Infrastructure Needs for Integration of Renewables and Distributed Generation (DG) [coordinated with EPRI IntelliGrid work]</td>
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<td>Protection Systems to Integrate Renewables and DG</td>
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<tr>
<td>Voltage and Var Control with Renewables and DG</td>
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<tr>
<td>DR Impact Assessment Workshop: This workshop will focus on best practices for accommodating high penetration of PV including advanced design concepts and options, microgrid results from Europe and the United States, and integrating renewables and distributed generation (DG) with automation schemes.</td>
<td>12/31/12</td>
<td>Workshop, Training, or Conference</td>
</tr>
</tbody>
</table>
### Impact of High-Penetration DR on Distribution System Performance:
Continues the 2011 analysis of the impacts of high-penetration solar PV and wind on distribution systems, including voltage regulation, feeder protection, regulator duty, and power quality (harmonics, flicker). Methods for maintaining system performance under high-penetration scenarios will be considered. Includes consideration of bulk system needs and potential impact on distribution system performance.

**Completion Date:** 12/31/12
**Product Type:** Technical Update

### DG Screener Analysis Tool Enhancements:
The DG deployment screening tool, DGScreener, driven by OpenDSS will be given added functionality, improved user interface and documentation, allow better access to new and advanced features of the OpenDSS, as well as additional case studies, circuit templates, and solar PV profiles.

**Completion Date:** 12/31/12
**Product Type:** Software

### Variability of Small and Large-Scale PV on Distribution Systems:
Provides analysis of actual PV systems to characterize the ramping and variability of both centralized, large-scale PV as well as distributed, small-scale rooftop PV dispersed throughout a distribution feeder. Analysis will quantify the extent to which PV system size and spatial diversity impact aggregate output characteristics.

**Completion Date:** 12/31/12
**Product Type:** Technical Update

### PS174B Power Electronic and Control Interfaces for Integration of Renewable Generation (067432)

#### Project Set Description
This project set focuses on end-user-level distributed renewable interface technologies, including advanced metering systems, inverters, controllers, and other related intertie equipment. It focuses on developing new grid functionalities for these devices, and it evaluates both the electrical power and communication interfaces for distributed energy resources (DER) and advanced metering infrastructure (AMI). The project set includes development of performance criteria, lab, and field testing.

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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P174.003</td>
<td>Communication for Intelligent Monitoring and Management</td>
<td>This project will continue the smart inverter communication initiative, moving from a survey-level to direct utility engagement, requirements assessment, and more hands-on and field applications. Communication interface evaluation in the laboratory continues.</td>
</tr>
<tr>
<td>P174.005</td>
<td>Evaluation of Power Converters and Grid Support Functions</td>
<td>Laboratory and field evaluation of distributed grid-interface systems for renewable generation and storage</td>
</tr>
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</table>
P174.003 Communication for Intelligent Monitoring and Management (067494)

Key Research Question

As technologies improve, distributed energy resources are increasingly able to perform a range of grid-supportive functions. These resources, which include photovoltaic and battery storage system inverters, typically have significant processing power and fast response times, enabling both steady state and dynamic grid benefits. With increasing deployment of these systems, many utilities also are making investments in related communications technology. Timing is critical for the development and testing of communication specifications and standard functional descriptions to prepare for future integration of distributed resources in higher-penetration scenarios. Results of the research are applicable to all utilities and a number of distributed technologies.

Approach

In prior years, this project engaged a broad group of stakeholders from utilities, inverter manufacturers, and communication system providers to work to establish uniform standard functions that could be built-in to off-the-shelf products and integrated into utility systems using open standards. Open standards have now begun to appear as a result of these efforts, and testing and evaluation in both laboratory and field environments is now possible. This project also conducted studies and laboratory evaluations of existing products to gauge the state of the industry in terms of device capabilities, efficiency, and reliability. Going forward, the project will continue to accelerate the availability of smart inverters and the standards necessary for their smooth integration into utility systems. It will increasingly include laboratory testing and field demonstrations that seek to identify incremental value streams and benefits of these devices.

Impact

- Informs and guides the PV and storage industries regarding the needs of utilities
- Accelerates availability of distributed energy devices that can be readily integrated into utility systems using open standards
- Identifies capabilities and limitations of various technologies
- Evaluates integration options, identifying architectures, best practices, challenges, standards gaps, and achievable results
- Helps members identify use case opportunities and learn from peer experiences
- Provides insight in how future supervisory control and data acquisition (SCADA), AMI, and other communication systems may be used to integrate distributed resources

How to Apply Results

Using the field experience and lessons learned reported in this project, members can refine plans for their own PV and energy storage integration. The opportunity for new value streams, system operating criteria, configurations, and integration architectures identified in this R&D program can be incorporated into specifications for existing distribution systems and customer interfaces and taken into consideration for new circuits accommodating high levels of renewable generation.

2012 Products

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tr>
<td>Open Source Application to Support Laboratory Evaluations and Field Demonstrations: This project will develop an open source software application based on the emerging DNP3 standards for PV and storage communication integration. It will provide members with a software tool that provides a graphical user interface through which the various monitoring and management functions can be exercised. A joint project with P94 (Storage) and P161 (Intelligrid).</td>
<td>12/31/12</td>
<td>Software</td>
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</table>
**Smart Inverter Communication Initiative - Industry Collaboration:** This project is a continuation of the EPRI-led industry initiative that is defining uniform functions and communication protocols for the exercise of these functions. This activity continues to provide thought leadership in this area and is contributing to the International Electrotechnical Commission (IEC), National Institute of Standards and Technology (NIST), IEEE, and a number of other standards organizations.

**Scoping Study on Metering Alternatives:** Survey and whitepaper to address the current status and future issues around secure, cost-effective metering of individual devices downstream of the utility meter at customer premises. A joint project with P180 (Distribution) and P161 (IntelliGrid).

**Strategies, Methods, and Algorithms to Manage Distributed PV and Storage:** Distribution management systems seek to provide optimal management of distribution devices, such as switches, capacitor banks, load tap changers (LTCs), and line regulators, in order to maximize overall benefits. The addition of smart (manageable) distributed PV and storage devices to distribution systems adds an additional variable. This project will study potential strategies and methods for the integration of distributed PV and storage and will identify algorithms for their management that coordinate their behavior with other controls.

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**P174.005 Evaluation of Power Converters and Grid Support Functions (067496)**

**Key Research Question**

Future grid interface systems that integrate renewable generation sources into distribution feeders are expected to provide grid support functions in addition to grid handshaking. With the introduction of many new grid interface systems there will be an increasing need to analyze and understand the impact and potential of these distributed and variable resources. Better understanding of balance-of-system (BOS) performance and use of storage to mitigate intermittency also is critical. Evaluating and demonstrating new smart inverters and other BOS hardware will position members to more effectively work with developers and customers wanting to deploy distributed renewable generation.

**Approach**

This project evaluates electrical performance, including interconnection, compatibility (immunity, emission, and energy performance), protection, and control options for inverters and other BOS hardware. It will define application-specific performance criteria and will include related lab testing and available field demonstration results for smart inverters with advanced grid support features. This project also will evaluate storage to minimize the intermittency of renewable energy sources.

**Impact**

- Hands-on evaluation of new interface hardware and systems with grid support functionalities will position members to more effectively deal with interconnection requirements.
- Benefits from collaborative evaluation activities and the shared results of field experiences, lessons learned, and solutions related to integrating distributed renewable generation.
- Insights on what to expect from deployment of distributed renewable power generation, with performance results on available interface systems.
How to Apply Results

Utilities faced with planning or integrating new renewable generation will use the results of this project to ensure that appropriate elements of safety, reliability, and electrical performance are considered. Utilities with relatively high penetration of renewable energy sources will learn about the grid support functions offered by new smart inverters. Findings can be used to work with system integrators wanting to connect renewable energy systems, construct zero-energy homes, and implement sustainable community strategies.

2012 Products

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<tr>
<td><strong>Laboratory and Field Evaluation of Selected PV Smart Inverters:</strong> Selected PV smart inverters will be tested in the laboratory for their grid interface and power quality performance. Special focus will be grid support functions like volt/VAR support, voltage and frequency sag/swell ride through, and real power curtailment. In some cases, testing will be accomplished in the field at host utility sites.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Evaluation of Grid-Connected PV-Battery System:</strong> This project will evaluate the effectiveness of storage systems to mitigate or minimize PV intermittency issue. Recorded and forecasted solar data will be used to command the charge/discharge rate of battery system to effectively limit fast ramping of power for the combined plant. Different operating modes, connection configurations, and sizing considerations will be addressed.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Evaluation of PV Panel-Level Power Converters:</strong> This project will develop performance test criteria to evaluate different types of PV panel-level power electronics. Field-measured solar irradiance data from geographically diverse locations will be used to perform laboratory tests of selected micro-inverters and dc-dc optimizers.</td>
<td>11/30/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Balance-of-System Performance Analysis:</strong> Knowing accurate balance-of-system (BOS) performance is of interest to the owners, as well as financial or utility entities providing funding and incentives. However, BOS efficiency depends on numerous factors including array design (dc bus voltage, cable run, string configurations), shading (from passing cloud and/or nearby object), inverter performance (MPPT algorithm, efficiency), and panel mismatch (aging, dust, debris). This project will develop and implement PV BOS evaluation system and techniques to independently monitor the performance of large PV arrays.</td>
<td>10/31/12</td>
<td>Technical Resource</td>
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PS174C Distributed PV Assets Operation, Maintenance and Reliability (070584)

Project Set Description

The project set addresses participants interest in applications best practices for operating, maintaining, and managing distributed PV assets as well as participants’ concerns about the reliability of these systems that may impact grid voltage and load flow. The scope includes evaluation of different models for utility ownership and operation of distributed renewable resources. The project set also evaluates inverter failure modes and limits, developing accelerated life testing and looking at different configuration effects on output performance and reliability.
P174.006 PV System Ownership and Asset Management (070585)

Key Research Question
As utilities contemplate PV system ownership and the prospect of rate basing an expanding amount of solar-based generation, they will be confronted by relatively new found system performance, reliability, and economic priorities. Unlike traditional power purchase agreements (PPAs) that place performance risk entirely on third-party providers, ownership shifts the financial onus onto utilities. Monitoring operation, implementing optimal management strategies, meeting production-related goals, and justifying the installation and operation becomes the utility's sole responsibility.

Approach
The approach for this project is to interview manufactures and system owners, gather and examine available industry site experience data, and collaborate with other researchers to consider how solar business models and future O&M requirements may evolve for utilities. Reviewing the results of prior or ongoing rate cases also may provide insights. EPRI will compare the body of existing knowledge on PV system installations to utility O&M needs and practices for other traditional utility assets such as poles, transformers, monitoring, and protection systems. It also will evaluate the existing and potential utility strategies for managing solar assets. Collectively, this information will be used together with direct input from members in a workshop setting to discuss best practices and to develop guidelines for managing this new asset type.

Impact
Provides comprehensive assessment of the operations and maintenance needs for future solar photovoltaic (PV) generation connected to utility distribution systems. These needs include maintenance practices, schedules, and labor requirements, as well as monitoring, control, reliability, and durability issues. In addition, the project set offers insights into evolving utility solar business models that provide multiple value streams and a pathway to handling a future that includes a high penetration of solar on the distribution network.

How to Apply Results
Participants can apply lessons-learned analysis provided by EPRI for all aspects of distributed PV asset management from installation, maintenance, and monitoring to O&M and asset management strategies. Differences in practices for utility-owned compared to customer- or third-party-owned assets also will be explored and utility best practices identified. Separately, subscribers will gain access to analysis and evaluation of the myriad solar business models being employed by utilities that capture multiple value streams (for example, financial, compliance-related, and customer acquisition). Insights into the structural make-up of utility solar strategies and their policy/regulatory context will be provided. Where possible, financial implications also will be examined.
## 2012 Products

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<tr>
<td><strong>Analyze Traditional Distribution Asset O&amp;M with PV Systems</strong>: Current O&amp;M practices employed by participating utilities on traditional distribution assets will be analyzed with the aim to understand PV system O&amp;M needs in the context of current asset practices. Issues to be considered include grounding, attachments, interference with vegetation, shading from trees, and lineman safety during inspections.</td>
<td>09/30/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Database Resource on PV Plant Performance and O&amp;M</strong>: This joint effort with Sandia National Labs will provide a comprehensive public database containing site data from installations throughout North America. Captured variables—assembled from both public and private sources—will include uptime/downtime metrics; inverter and BOS equipment types; discerned failure events, causes, and frequencies; and locational factors, among others. Pending adequate sample size requirements, scenario-based modeling also will be performed to provide contextual analysis of cost-effective O&amp;M approaches. These findings will be relayed in a formal report.</td>
<td>09/30/12</td>
<td>Technical Resource</td>
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<tr>
<td><strong>Database Resource on Solar PV Utility Asset Ownership</strong>: Provides a members-only site for accessing a detailed library of information concerning solar PV utility asset ownership activities, strategic approaches, and regulatory decisions. The online library will include a database of regulatory filings, testimonies, and decisions; case studies summarizing utility PV ownership initiatives; and white papers that detail utility best practices, distill filing trends, and characterize public utility commission opinions. This activity extends ongoing collaboration with the Solar Electric Power Association (SEPA), which has provided reference documents and summaries that address utility ownership cases.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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<tr>
<td><strong>Database Resource on High Penetration PV Projects</strong>: Provides a searchable database for comparing and contrasting the status, developments, and results of worldwide high-penetration solar PV project demonstrations. The scope of the database’s coverage will encompass those demonstration projects that have secured funding and involve distributed PV (for example, semiconducting and thin-film materials, inverters, power electronics) and/or energy storage components—the systems integral to enabling a high penetration of PV on the distribution grid. In addition, case studies will be developed for a select number of demonstrations to present a more descriptively nuanced assessment of project-related advances, shortcomings, and next steps. The briefs will provide concise analysis of specific project developments that are expected to more broadly impact the grid integration of PV. Periodic webcasts also will be broadcast to report on the databases’ development status and to highlight latest project activities of interest.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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<td><strong>Develop Scenarios for Future Utility O&amp;M Practices</strong>: Workshop on industry practices surrounding utility solar acquisition strategies as well as utility and PV industry O&amp;M experience</td>
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<td>Workshop, Training, or Conference</td>
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<tr>
<td><strong>Utility Solar Business Models</strong>: Details the diversity of innovative approaches that utilities are employing to acquire solar energy resources, providing best practices examples, filing trends, and a characterization of public utility commission opinions. This activity extends ongoing collaboration with the Solar Electric Power Association (SEPA), which has provided reference documents and summaries that address utility ownership cases and other methods of acquisition.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P174.007 Converter Reliability, Failure Modes and Life Testing (070586)

Key Research Question
As utilities contemplate expanded deployment and increasing penetration of PV systems, the inverter will become a critical component in distribution circuit operation. Critical functions include capture of array energy, collaboration on reactive power control and circuit voltage regulation, fault ride-through, and response to protection and dispatch commands. With higher levels of distributed PV integration and increased dependence on the operation of these resources, a more detailed understanding of controls, protections, and failure modes will be needed.

Approach
The approach will be to apply proven utility industry techniques for developing performance and screening criteria, conduct device analysis including the same level of proof and testing used for relays, metering, and other critical components. Issues related to infant mortality, mean time between failure (MTBF), component stress, and wear out will be addressed, including thermal, electrical, and mechanical. Also, different configuration options (central vs. distributed) that change series and parallel connection and single-point failure exposures will be evaluated. Techniques of accelerated life testing (ALT) will be applied for unproven designs. Participants input and prioritization will determine the final deliverable plan.

Impact
Typically, inverter failures have accounted for 80% of system downtime. Since these systems are currently not critical to operation of the distribution system, there is relatively little data available on how inverter and other BOS equipment reliability affected operating costs. With a trend to higher penetrations of these devices, this project focuses on the inverter interface and performance as a critical component in distribution as if it were a relay, a transformer, or a revenue meter.

How to Apply Results
Results will inform distribution utilities about what can be expected from inverter additions to the grid. Anticipating increasing operation on these PV systems, results from this project can be used to compare other critical components in the distribution system as well as to inform decisions related to purchasing specifications and acceptance criteria.

2012 Products

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<tr>
<td><strong>Quality Control and Product Screening Criteria for Advanced PV Inverters:</strong> This project will develop quality control and product screening criteria for PV inverters based on the same level of proof and testing practiced by the utility industry for relays, cap banks, LTCs, energy meters, and other critical components.</td>
<td>09/30/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Results of Accelerated Life Testing for Selected PV Inverter System:</strong> Accelerated life testing (ALT) is a widely exercised method to evaluate system reliability in relatively short periods of time. This project will report results of ALT for selected PV inverters. Wear out will be evaluated, including thermal, electrical, and mechanical stress for selected PV inverter products.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>PV Inverter Reliability Survey:</strong> This project will design and initiate a field survey to develop a knowledge base for PV inverter reliability analysis. Goal will be to collect reliability-related data including failure modes, failed components, and related system impacts (downtime, production loss, repair cost) from large PV installations for several years.</td>
<td>09/30/12</td>
<td>Technical Resource</td>
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Supplemental Projects

Demonstration of PV Inverters with Smart-Grid Functionality (072098)

Background, Objectives, and New Learnings
To achieve high penetration of photovoltaic (PV) generation in distribution systems, PV inverters need to become utility assets rather than just continuing to be negative loads relative to the feeder and end user facilities. Approximately 20 GW of PV is currently operating in the world—mostly connected at the distribution level—without actively supporting the utility grid. Many inverter manufacturers understand the potential that power electronics have for advanced grid-friendly behavior. However, these resources are limited in their practical operation due to the restrictions imposed by existing standards and practices that were designed with low-penetration levels in mind. The aim of this project is to evaluate and demonstrate the smart grid functionalities currently offered by several inverter manufacturers and applied into a grid connected PV system. Results are expected to significantly increase the understanding of how to deploy and utilize distributed PV systems more effectively.

Project Approach and Summary
This project will demonstrate how distributed PV systems can provide grid functionality through the application of smart inverters. The advance functions desired from these distributed resources include the following:

- autonomous and scheduled volt-VAR support for point of coupling active voltage regulation
- fault ride through to stay online during the transient grid disturbances like sags and swells
- extended operating voltage and frequency ranges to avoid nuisance tripping
- ability to act on utility commands for connect/disconnect and real power curtailment through maximum generation level setting for distribution system asset protection

This project will model and analyze each feeder and demonstration site to show the affects of adding new functionalities and in changing the penetration levels of distributed PV on the feeder. Pre- and post-demonstration feeder simulations and analysis will validate the system reliability and quantify the benefits of PV inverters with smart-grid functionalities for the specific location. Host utility and PV plant inverter manufacturers are expected to install a new inverter or retrofit an existing unit to enable the grid support functions mentioned above.

Benefits
This project will demonstrate PV inverters with smart-grid functionality in an actual PV system. Expected benefits include the following:

- Better utilization and integration of renewable resources on feeder level which may lower environmental impact by limiting carbon emissions usually associated with generating electric energy using fossil fuels, and may help the public to meet renewable portfolio standards
- Identify potential for deferral of investments on capacity expansions and voltage regulation equipment, including extending life of existing switches by minimizing switching activity
- Enabling higher penetration of PV systems in the distribution feeder without significant feeder upgrades
- Accelerate the availability of smart inverters in the marketplace through contribution of this project to understanding the issues and in formation of better industry standards
Active Prevention of Unintentional Islanding for Distribution Operators (072099)

Background, Objectives, and New Learnings

The anti-islanding mechanisms that are currently identified for individual inverters in IEEE and UL standards are not adequate for high-penetration scenarios. As distributed generation resources become more prevalent, interactions between different inverters and the potential for generation that is closely matched to load may cause traditional anti-islanding techniques to fail. The potential is compounded by advanced inverter behaviors. The more that inverters act to stabilize system voltage and frequency around normal levels, the more inclined a system becomes toward unintentional islanding because of the system’s inherent stability. This project will study and identify a workable mechanism for positive island detection, evaluate the mechanism through field trials, and provide coordination and contribution to standards organizations to accelerate the adoption of this capability.

Project Approach and Summary

The project will investigate the use of an always-on power-line signal that is generated at the substation and received by distributed resources to inform them that connectivity to the substation exists. The idea is that whenever the signal path is broken, whether from an opened switch or line failure, the distributed devices will be able to avoid unintentional islanding by taking appropriate action. This project is the first part of a multi-phase activity intended to lead to a uniform open standard for active prevention of unintentional islanding. The first phase will leverage existing power-line communication technologies to prototype and demonstrate to concept. It also will perform an international search for applicable technologies and intellectual property related to this application. Field evaluations will be conducted using test feeders and distributed resources that may be provided by project participants.

Benefits

There are a number of benefits that could be realized through this project. They include:

- A solution to unintentional islanding may remove one key impediment to the adoption of renewable energy and storage technologies.
- Engages communication providers and inverter manufacturers in implementing and evaluating a practical solution
- Provides real-world evaluation through evaluation in an actual member utility distribution system
- Accelerates the availability of products in the marketplace through contribution to standards organizations
Application of DMS Control and Communication for Distributed Generation (072100)

Background, Objectives, and New Learnings
Approximately 20 GW of distributed PV is currently operating worldwide, the vast majority without communication or manageability from the local distribution operator. The power electronics used to interface distributed resources to the grid (for example, PV inverters, battery controllers, and electric vehicle battery chargers), are generally capable of more positive interactions with grid operators. However, these resources are limited in their field usage for lack of visibility to time varying grid requirements. The aim of this project is to complete and demonstrate the end-to-end communication link between distribution operators and distributed resources in several different field applications and environments. Results are expected to directly contribute to understanding and to effective deployment and integration of future distributed energy resources. Experience gained from this project will help inform the standards making process for more active participation of distributed energy resources.

Project Approach and Summary
This research project will develop a needed head-end application software that provides a human interface for the configuration, management, and monitoring of smart distributed resources. As possible, the software will draw in system status information from existing SCADA systems. The software will be research oriented, serving as a tool to help identify best practices for the management of smart distributed devices in coordination with existing distribution data and controls such as capacitor banks and regulators. The software will implement and utilize emerging DNP3 protocol standards, assessing the capabilities, limits, and limitations.

The findings of this project and the practices identified are intended to integrate into distribution management systems (DMS) of the future at the control center or substation level. At field locations, a site controller or communication-ready inverter system will communicate using the DNP3 protocol. Standardized functions for distributed resource inverters continue to be defined on the national and international stage. These functions will be demonstrated at select field sites of participating utilities using the software tool developed in this project. This will, in effect, connect the grid operator and the distributed resource and will allow the resources to be managed in beneficial coordination with existing controls.

Benefits
The public expected public benefits of this project may include
- Adoption of methods developed in this project are expected to enable higher penetration of PV systems distribution and to help meeting renewable portfolio standards and lower a possible carbon emissions
- The learning from this project will contribute to more effective operations, maintaining safety and reliability. This may enable more customers to install photovoltaic systems.

Participants may benefit by gaining experience in these new methods and technologies and by understanding their applications. they include:
- Implementation experience of communication protocols expected to become industry standards
- Understanding the issues when interfacing existing controls with new DNP3 protocols
- Optimizing the utilization of distributed resources in coordination with existing controls
- Building internal experience with active control of distributed resources
- Understanding the options for harmonizing smart inverter controls with existing data and systems
Flat Plate Photovoltaic Collaborative Testing at Solar Technology Acceleration Center (070976)

Background, Objectives, and New Learnings

Traditional crystalline silicon photovoltaics (PV) are and will continue to be costly, but there is insufficient experience with many of the newer, potentially cheaper PV technologies to warrant large-scale, long-term investment. The efficiencies of new flat-plate technologies are tested extensively in laboratories, as cells and as modules, to make manufacturing decisions. But only unbiased larger-scale and longer-term trials in the actual operating environment (i.e., outdoors) will suffice for commercial acceptance of these new technologies. Banks and utilities are likely to wait for the results of early field tests to gain confidence in the reliability of new PV technology.

A recent EPRI study (EPRI document # 1021320) compared six categories of commercially available PV technologies and estimated their performance in different climates. These technologies, and specific products within these categories, have achieved different levels of maturity. Several new products have the potential to be lower cost with better performance than today’s commercially available technologies.

The Solar Technology Acceleration Center (SolarTAC) is the largest test facility for solar technologies in the United States. It offers a venue for the collaborative development of solar energy technologies and products (see www.solartac.org). EPRI’s membership in SolarTAC provides a proving ground for both emerging and near-commercial technologies.

This collaborative project will reduce performance uncertainty of PV technologies through an independent assessment in a real-world operating environment. The project could help pave the way for future PV projects to be developed at lower cost and with better performance.

Project Approach and Summary

The project objective is to independently assess the performance and reliability of a variety of PV technologies in a real-world setting. This project will assess the site requirements, installation, commissioning, performance (at least one full year of operation), reliability, and O&M requirements of multiple PV technologies.

The demonstration testing will be initiated at SolarTAC in Aurora, Colorado, and additional locations also may host demonstrations to better understand performance in a broader range of climates. Systems will likely be in the 5-10 kW size range. The number of systems to be tested will be determined by available funding.

During installation, EPRI will work with on-site developers to understand any installation issues. Standard testing protocols will be developed and monitoring systems implemented to capture key performance metrics. A suite of meteorological measurements will be taken to compare expected performance with actual system outputs. Ramping during cloud transients is of particular interest.

O&M activities and expenditures will be reported and best practices for preventative maintenance will be recommended based on experience. Performance data will be analyzed to identify lost generation potential, and the failure modes and countermeasures implemented will be documented and reported.

As with any early systems, significant learning is expected to take place, and best practices will be communicated to participants throughout the project. Potential means of improving the cost-effectiveness of the systems will be identified by EPRI and technology providers.

Benefits

This program offering will provide real data on emerging solar technologies that will allow energy companies to make educated solar investment decisions.
Distribution Systems - Program 180

Program Overview

Program Description
Utility distribution systems are at the center of the smart grid revolution and are challenged by aging infrastructure, legacy systems that must be integrated with new technologies, changing load characteristics (such as electric vehicles), and the requirement for integration of widespread distributed energy resources. Given these challenges, electricity distribution companies are under pressure to improve reliability and system performance, build the necessary infrastructure to integrate distributed energy resources, and deal with changing load characteristics, usually under severe budget constraints. The efficiency of the distribution system operation continues to increase in importance and, of course, safety always takes the highest priority.

New technologies will be critical to future smart grid operation. A smart grid must integrate widespread distributed energy resources as part of the normal operation of the system. In addition, the distribution management system, automation systems, protection systems, and planning tools must be designed to overcome this challenge.

EPRI’s Distribution Systems Program has been structured to provide utilities with research and application knowledge to support smart grid implementation and with tools for planning, design, maintenance, operation, and analysis of the distribution system. Members of the program have access to a portfolio of projects that cover the realm of distribution issues, as well as the opportunity to collaborate with other members and EPRI technical experts to share ideas and solutions, improve knowledge transfer, and ultimately improve operational performance.

In close collaboration with its members, EPRI has published a 10 year forward looking Distribution Research Area Strategic Plan (1022335) to articulate its research objectives. This strategic plan is a living document and is under continual refinement by the funding members so that the research being conducted by EPRI is aligned and prioritized with the real needs of the industry. This document is publicly available.

Research Value
With the knowledge acquired through this research program, members will have access to information that can help them do the following:

- Plan and operate a smart distribution system.
- Improve diagnostics, inspection and assessment methods, tools, and techniques.
- Optimize component procurement specifications and equipment application guidelines to improve investment decisions.
- Enhance the location and prediction of system fault locations as part of an overall distribution management system.
- Provide new approaches and strategies for managing underground distribution systems.
- Support the implementation of advanced distribution control functions for reliability improvement, voltage control, and integration of distributed resources – the smart grid.
- Plan for efficiency improvements and new technologies with existing planning models and approaches.
- Assess the economics and benefits of new smart grid applications and advanced technologies.
- Integrate advanced metering and other distributed sensor technologies with planning and operational models and systems.
- Understand industry leading practices in the management and operation of distribution systems.
Approach

The EPRI approach for providing value in the distribution research program involves multiple strategies:

1. **Basic research.** Research into new technologies, practices, and tools provide the foundation for ongoing advancements in the industry. This research includes new technologies, such as nano dielectric cables and the solid-state transformer, as well as the foundation for new tools for simulating and analyzing the performance of the distribution system.

2. **Testing.** The work conducted in EPRI laboratories and in cooperation with other industry centers of excellence enables detailed assessment of equipment performance, application issues, and aging characteristics.

3. **Development of application and assessment guidelines and approaches.** Basic research results need to be translated into approaches that can be used by members to plan, manage, and operate the distribution system of the future.

4. **Industry knowledge databases.** EPRI collaboration facilitates collecting industry-wide information that can help program members understand important trends and characteristics related to equipment and systems.

5. **Technical information transfer and sharing.** This strategy includes active participation in industry groups such as the Institute of Electrical and Electronics Engineers (IEEE); a 24/7 hotline to deal with specific member issues; interest groups to coordinate information sharing on urgent topics; and workshops, conferences, and training in emerging research areas.

Accomplishments

EPRI's Distribution Systems research program has delivered valuable information that has helped its members and the industry in numerous ways:

- In 2010, EPRI research determined that portable electronic device technology (PEDs) will present significant opportunities in the handheld meter/diagnostic device arena and could become a major component of the smart grid sensor market. These devices will be used to stream, store, and selectively upload data from a remote location to a centralized location. EPRI has evaluated five potential applications and completed successful demonstrations.

- EPRI recently published the first edition of the *Underground Distribution Systems Reference Book (Bronze Book)*. This reference book contains the most up-to-date technical information on underground distribution systems, with sections on the state of the industry, underground distribution design, reliability, construction and installation practices, operations and maintenance, and distribution equipment. Authored by industry recognized experts and supported by almost 40 different utilities, this reference directly supports a key strategic need of utilities facing a rapidly changing business and technical environment — to capture and document institutional knowledge.

- EPRI and Consolidated Edison of New York (Con Edison) have collaborated to develop technology that will alert workers to the presence of low-voltage system cable faults (arching) in underground structures. The result of this collaboration is the development of a prototype safety device that warns workers of electrical arcing before they enter a structure and continuously monitors for arcing as crews work.

- EPRI has conducted groundbreaking research on distribution systems arc flash issues in collaboration with over 20 utility members. This research has included extensive laboratory testing and analysis. This effort has uncovered important new learning about arc flash behavior that can inform utilities about arc flash energy calculation methodologies, system operation and work rule implications, and personal protective equipment. Participating utilities have implemented results that have "moved the needle" for the safety of utility workers.

- The OpenDSS Software has provided an open source platform for the industry to evaluate new distribution system modeling and simulation concepts that apply to both planning and real time applications. It has been used as a foundation for new load model development (voltage optimization collaborative and green circuits), energy storage integration modeling (AEP), electric vehicle penetration assessments, and many other applications.
EPRI has published an industry database of leading distribution systems practices. The knowledge base is providing a growing library of innovative practices for managing and operating distribution systems that can be directly applied by members to improve their own operations. EPRI uses a research in action method known as immersion to capture and collect the information, immersions have been conducted at over 20 utilities.

**Current Year Activities**

In the current year, research program objectives include:

- Perform component and accelerated aging analysis on key industry assets such as electronic recloser control systems
- Develop, apply and demonstrate advanced fault prediction and location algorithms
- Conduct workshops on distribution systems leading practices and key reliability drivers
- Conduct technology assessments and evaluations for smart distribution system applications such as voltage optimization and automatic circuit reconfiguration
- Develop guidelines to aid utilities in integrating distributed resources and applying Distribution Management Systems (DMS)

**Estimated 2012 Program Funding**

$7.0M

**Program Manager**

Matthew Olearczyk, 704-595-2743, molearcz@epri.com

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**Summary of Projects**

**PS180A Distribution Planning, Design, and Analysis (070606)**

**Project Set Description**

This project set focuses on modern tools for planning and design of distribution systems, new analysis methods, new modeling approaches, and incorporation of distributed resources into the planning process. Planning and design of electric distribution systems are undergoing dramatic changes in the world of the smart grid. In the past, distribution planning focused on maintaining acceptable electrical conditions in the steady state during peak load conditions and minimum load conditions. With the growing penetration of distributed energy resources (including highly variable renewable generating resources), there is a need to analyze and plan for dynamic operating conditions that can occur at any time throughout the year. The rapid growth of small-scale distributed generation (such as rooftop solar) has created the potential for a considerable number of “zero net energy” homes, which presents a major challenge for short- and long-term load forecasting.

Modern tools are needed to evaluate and mitigate the impact of these fundamental changes to the distribution system characteristics. Planning tools must be able to evaluate distribution performance over annual profiles with many factors affecting load levels and characteristics.

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<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>P180.001</td>
<td>Tools, Methods, &amp; Modeling for Dynamic Distribution Systems</td>
<td>This project focuses on developing and demonstrating advanced analysis tools for modeling and planning modern distribution systems that include a high penetration of distributed energy resources, including renewable generating resources with highly variable output. Open Source software is used to demonstrate these concepts so that they can easily be incorporated into a variety of commercial systems.</td>
</tr>
</tbody>
</table>
P180.002 Load Forecasting for the Modern Distribution Grid

This project includes the development of new methods for short- and long-term load forecasting for planning and operation of the smart distribution grid. These new methods must take into account the effects of widespread distributed generation, demand response, and energy efficiency measures on the distribution feeder and growing potential for zero net energy residences and commercial establishments.

P180.001 Tools, Methods, & Modeling for Dynamic Distribution Systems (070607)

Key Research Question

Smart distribution systems will incorporate a variety of new control and system optimization functions, as well as the ability to integrate a wide variety of distributed resources. These functions will take advantage of advanced sensors, system communication infrastructure, new switchgear technologies, and new modeling and simulation capabilities. These functions, which may be implemented as part of overall distribution management systems (DMS), need to be characterized and evaluated within the distribution planning and design process. Key research issues involve the evaluation of modeling requirements and approaches for the design of distribution systems that take into account these advanced functions.

Approach

This project will develop modeling approaches and analysis methods for evaluating the dynamic effects of distributed energy resources and associated controllers on distribution system performance, efficiency, and reliability. The modeling methods will be implemented in Open Source software using actual distribution system designs and models to demonstrate the new approaches. Important issues to be addressed include:

- Detailed modeling of dynamic elements, including distributed generating (DG) units and associated controllers. What new information is needed to properly model distributed energy resources (DERs), including customer owned generating equipment that is connected to the distribution feeder.
- The types and sizes of DERs that need to be considered in the analysis. Can some small units be ignored without impacting the analysis.
- Real-time and non-real-time information needed to support the analysis. This includes electrical parameters as well as weather-related information that impacts the output of renewable energy resources (wind, solar, etc.).
- New capabilities required in distribution engineering analysis tools for performing dynamic analysis.

Impact

The tools and guidelines developed will be demonstrated with real world distribution systems to illustrate the new approaches:

- The true value of advanced automation functions and distributed resources cannot be realized until these technologies and systems are incorporated into the distribution system planning and design process.
- The project will continue to develop the planning and design tools and methods so that distribution system designs can be optimized based on available technologies and systems.
- The project will publish guidelines for system planning and design that take into account requirements for reliability improvement, with design objectives for reduced losses, and improved voltage control.
How to Apply Results

- Members will be able to better plan investments in smart distribution applications through an understanding of application requirements and performance under different circumstances.
- Members will be able to use the Open Distribution System Simulation software (OpenDSS) as a platform for evaluating advanced applications for their own distribution systems. Example applications will provide templates for these evaluations.
- Members will be able to assess the economics and benefits of different applications as a function of their implementation costs.

2012 Products

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<td><strong>Tools, Methods &amp; Modeling for Dynamic Distribution Systems</strong>: The report will focus on developing and demonstrating advanced analysis tools for modeling and planning modern distribution systems that include a high penetration of distributed energy resources, including renewable generating resources with highly variable output. Open Source software is used to demonstrate these concepts so that they can easily be incorporated into a variety of commercial systems.</td>
<td>09/30/12</td>
<td>Technical Update</td>
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</table>

P180.002 Load Forecasting for the Modern Distribution Grid (070608)

Key Research Question

The rapid growth of small-scale distributed generation, such as rooftop solar, has created the potential for a considerable number of “zero net energy” homes, which presents a major challenge for short- and long-term load forecasting. Modern tools are needed for short-term and long-term load forecasting to evaluate and mitigate the impact of these resources to the distribution system characteristics. Planning tools must be able to evaluate distribution performance over annual profiles with many factors affecting load levels and characteristics.

Approach

Distribution system modeling tools can now accommodate distributed generation, new customer load characteristics such as voltage dependency (more detailed models are being developed as part of an industry wide supplemental project), and even demand response. These tools enable distribution engineers to evaluate and mitigate the impact of distributed energy resources (DERs) on electric system performance, efficiency, and reliability. Now we need to develop tools and methods for determining the effects of DERs on short-term and long-term load forecasting and develop the guidelines for using these tools as part of the basic distribution planning process.

This project will develop load forecasting guidelines for planning electric distribution systems that include a high penetration of DERs resources. The potential impact of zero-energy residences, commercial establishments, and communities pose special challenges for traditional load forecasting methods. The load forecasting guidelines will consider the impacts of distributed generation (including renewables), storage, voltage optimization, and demand response.

Impact

- New distribution designs and investment decisions will be able to take advantage of widespread demand response and other distributed resources.
- Implementation of planning processes that incorporate demand response and distributed resources will permit more optimum investment decisions.
• Distribution benefits of distributed resources are included in the business case for these technologies. Therefore, the methods for assessing the actual value and impacts on distribution designs must be available.

How to Apply Results
Distribution planners will use the methods and protocols to evaluate distribution investment decisions, including the impacts of energy efficiency and demand response programs and technologies.

2012 Products

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<td>Load Forecasting for the Modern Distribution Grid: This report includes development of the new methods for short- and long-term load forecasting for planning and operation of the smart distribution grid. These new methods must take into account the effects of widespread distributed generation, demand response, and energy efficiency measures on the distribution feeder and growing potential for zero net energy residences and commercial establishments.</td>
<td>11/30/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

PS180B Distribution Inspection, Maintenance, Asset Planning (070609)

Project Set Description
This project set is designed to help utility asset managers by providing component reliability and infrastructure inspection-assessment information and knowledge. Laboratory testing is combined with actual field data to build an industry database and provide a better understanding of component reliability, equipment remaining life, fleet populations, and life cycle cost.

<table>
<thead>
<tr>
<th>Project Number</th>
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<th>Description</th>
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<tbody>
<tr>
<td>P180.003</td>
<td>Component Reliability</td>
<td>This project builds and maintains an industry equipment reliability and performance database that addresses components, equipment performance, failure characteristics, and fleet populations.</td>
</tr>
<tr>
<td>P180.004</td>
<td>Inspection, Diagnostics &amp; Life Extension</td>
<td>This project will provide utility asset managers with distribution system inspection methods, practices, and techniques and will conduct unbiased technology evaluations of new inspection techniques.</td>
</tr>
</tbody>
</table>

P180.003 Component Reliability (070610)

Key Research Question
Quantifying distribution component reliability can be challenging for utilities, especially without a formal analysis program. The issue becomes more difficult when manufacturers make design and material changes that can have impacts on reliability. Improved understanding of component reliability can be gained through a framework of testing and data collection. This information can then be used to support the fundamental cycle of asset management including evaluating component design, selecting the right component for the task, assuring proper component installation, performing focused inspection and assessment, and prioritizing replacements.
Approach

This project focuses on components on an individual basis and also on component systems (overhead capacitor installations, for example) and builds and maintains an industry database. Laboratory testing is combined with utility survey and field data to enhance the database and provide a better understanding of individual component reliability and operational parameters that affect reliability. The laboratory component of this work features a multi-stress accelerated aging method that includes electrical, mechanical, ultra-violet, salt fog, and flammability testing.

Impact

Optimized distribution component selection, application, and inspection yield:
- Improved specification and purchasing decisions
- Enhanced distribution system reliability
- Reduced distribution system operating costs
- Improved safety for utility personnel and the general public

How to Apply Results

Project results will be delivered in an annual industry workshop, test reports, field references, inspection guides, and other training materials. Results will also be compiled into the Distribution Component Reliability and Specification Guidebook, and members can directly apply this information to enhance their procurement, design, operation, and inspection practices.

2012 Products

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<tbody>
<tr>
<td>Component Reliability: This project builds and maintains an industry equipment reliability and performance database that addresses components, equipment performance, failure characteristics, and fleet populations. The industry workshop will provide a summary of all results in a training style format.</td>
<td>10/31/12</td>
<td>Workshop, Training, or Conference</td>
</tr>
</tbody>
</table>

P180.004 Inspection, Diagnostics & Life Extension (070611)

Key Research Question

Outages that are caused by failing infrastructure are costly for utilities and end-use customers. Routine inspection programs are one tool that utilities can use to reduce failures on their circuits and minimize customer outages. By identifying problems that need repair before they develop into failures, inspection programs can be a cost-effective method for enhancing the quality, reliability, and safety of electric service.

Approach

This work will provide distribution utilities with the necessary information to accurately perform meaningful inspections that will enhance distribution system reliability and operations. This information includes improved methods for performing basic inspections and the development and implementation of new inspection technologies.

Impact

Optimized distribution inspection technologies and procedures yield:
- Fewer service outages
- Improved power quality and reliability
- Reduced outage repair costs
How to Apply Results

Project results will be delivered in an annual workshop, test reports, field and inspection guides, and other training materials. Results will also be compiled into the *Distribution Circuit Inspection and Assessment Guidebook*, and members can directly apply this information to enhance their procurement, design, operation, and inspection practices.

2012 Products

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<tbody>
<tr>
<td><strong>Inspection and Assessment Methods:</strong> Research results will provide utility asset managers with distribution system inspection methods, practices, techniques and unbiased technology evaluations of new products and services.</td>
<td>10/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

**PS180C Cable Systems Management (070612)**

**Project Set Description**

This project set focuses on the cables and cable systems associated with underground distribution systems. The goal is to provide members with guidance for cable and cable systems selection, installation, operation, and maintenance, as well as a basis for justifying a replacement management strategy for cable fleet populations. The project set builds on previous work in to assess the latest approaches for diagnostics and cable fleet management.

<table>
<thead>
<tr>
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<th>Description</th>
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<tbody>
<tr>
<td>P180.005</td>
<td>Methods for Cable Fleet Management</td>
<td>Develop, adapt, and enhance risk-based research to help identify optimal fleet management strategies for installation, replacement, rejuvenation, and maintenance of underground cables and cable systems.</td>
</tr>
<tr>
<td>P180.006</td>
<td>Advanced Cable Diagnostics</td>
<td>This project expands on earlier EPRI work and will build on its collaborative effort with the Department of Energy and in the Cable Diagnostics Focused Initiative (CDFI) with the help and partnership of other industry and utility experts.</td>
</tr>
</tbody>
</table>

**P180.005 Methods for Cable Fleet Management (070613)**

**Key Research Question**

Segments of the electric distribution system underground infrastructure have been in service for many years, and in some cases beyond their design life. Many companies face substantial future costs to replace aging underground distribution cables and cable systems. Today, utility decisions are made under stringent expense controls, limited capital, and increased public concern about reliability. These factors combine to make well-informed decision making more crucial and yet more elusive than ever. Developing and justifying a replacement management strategy for cable fleet populations, and the rational basis for it, are increasingly important.

**Approach**

EPRI will conduct research to help identify optimal fleet management strategies for installation, maintenance, health assessment, rejuvenation, and replacement of underground cables and cable systems. Essential steps in this development include identification of economic and business case scenarios, assessment of the quality and availability of data relevant to these types of problems through detailed work with host utilities, and identification of the successful application of cable fleet management methodology concepts.
Impact

- Help utility asset managers deal with the problem of aged cable and cable system populations.
- Formulate innovative methodologies to justify investment strategies.
- Ensure effective cable management programs.

How to Apply Results

Underground cable fleet managers can use the results of this project to better understand and improve cable selection, procurement, replacement, rejuvenation, and maintenance strategy.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Cable Fleet Management - Strategy, Technology and Implementations:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</tbody>
</table>

P180.006 Advanced Cable Diagnostics (070614)

Key Research Question

North America has a significant underground electric distribution system that is nearing the end of its design and service life. Global replacement of aging underground facilities is not an option, and utilities require better diagnostic methods, technologies, and tools to assess the condition of installed systems. Knowledge of cable condition provides utilities with a basis for implementing a staged rejuvenation or replacement program over a number of years and helps avoid unexpected costs associated with increasing failure rates. The utility industry has focused on cable diagnostics for many years, but is still facing uncertainty and confusion regarding the effectiveness and accuracy of cable diagnostic testing techniques and methods.

Approach

This project expands on a body of earlier EPRI work on diagnostics methods and approaches. Particularly challenging are hybrid circuits with mixed paper-insulated lead-covered (PILC), cross-linked polyethylene (XLPE), and ethylene propylene rubber (EPR) dielectric systems, as well as highly branched networks. Recently completed research on new diagnostic technologies reveals the potential of new methods that, when combined with conventional partial discharge and dissipation factor measurements, could enhance the prediction of future performance and service life of cable circuits. EPRI intends to expand the scope of this project and will build on its collaborative effort with the Department of Energy-sponsored Cable Diagnostics Focused Initiative (CDFI).

Impact

- Deliver technology and case study reviews.
- Provide methods to establish the condition of aged PILC and extruded dielectric distribution cables.
- Enable prioritization of cable replacement, minimizing the present cost of cable replacement programs.
- Fosters improved reliability through enhanced knowledge of the condition of installed underground assets and active replacement of those with the least remaining life.

How to Apply Results

Utility engineers will be able to apply information from technical reports, webcasts, and workshops on cable diagnostics to more effectively identify those assets in need of repair or replacement due to aging.
2012 Products

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<tr>
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<th>Planned Completion Date</th>
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<tbody>
<tr>
<td>Advanced Cable Diagnostics: This report will document EPRI-directed research into advanced cable system testing and diagnostic techniques. A progress update of the Department of Energy–sponsored Cable Diagnostic Focused Initiative (CDFI) will be included.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

PS180D Distribution Reliability Management (070615)

Project Set Description

This project set is focused on managing distribution reliability. The project set will help develop and evaluate advanced approaches for calculating, tracking, and reporting reliability performance, including coordination with the activities of IEEE 1366. In addition, the project set will develop and evaluate approaches for designing distribution systems for reliability (applying analytical tools) and selecting the optimum methods for improving reliability as a function of distribution system characteristics. This work involves both technical and economic assessment methods. Managing fault performance is a key aspect of managing reliability. The project set includes continued advancement of fault location approaches, fault analytics, and methods to reduce the number of faults.

<table>
<thead>
<tr>
<th>Project Number</th>
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<th>Description</th>
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<tbody>
<tr>
<td>P180.007</td>
<td>Fault Location &amp; Anticipation</td>
<td>EPRI has developed and tested technologies to make fault location systems easier for utilities to install and use. Such systems allow operators to view the estimated location of a fault, which helps operators direct crews to do switching and locate faults faster.</td>
</tr>
<tr>
<td>P180.008</td>
<td>Reliability Practices and Drivers</td>
<td>This project identifies leading practices and guidelines for improving distribution reliability. The core activity of this research is the identification and documentation of leading practices for maintaining and improving distribution system reliability.</td>
</tr>
<tr>
<td>P180.009</td>
<td>Reliability Metrics and Special Topics</td>
<td>This project will coordinate with the activities of IEEE 1366 to help advance the state of the art in calculating reliability metrics, adjusting for major events and applying normalization approaches to make the reporting more useful.</td>
</tr>
</tbody>
</table>

P180.007 Fault Location & Anticipation (070616)

Key Research Question

Previous EPRI research in this project and utility implementation experience have shown that fault location can be used successfully to reduce repair and restoration times. Work in 2011 is showing excellent preliminary results for applying advanced fault location algorithms to incipient fault events that can be precursors to cable splice failures and arrester failures. Key research questions include determining the extent to which this technology can be applied for different types of distribution systems and establishing the percentage of cable splice failures and arrester failures that could exhibit these precursor events.

Approach

EPRI has developed and tested systems to make fault location systems easier for utilities to install and use. Such systems allow operators to view the estimated location of a fault, which helps operators direct crews to do switching and locate faults faster. These systems also locate temporary faults, so that problem locations can be identified before permanent faults occur. Along these lines, current research is extending the algorithms for
locating incipient faults. The main goal in 2011 is to test the performance of this system based on a larger library of field events and then to investigate ways that the effectiveness can be improved through combinations of technologies such as:

- Integration of fault indicator data with substation-based fault location
- Advanced meters and triangulation
- Integration of data from automated feeder devices such as reclosers, switches, capacitors, and regulators

**Impact**

- Identify temporary fault locations to improve maintenance strategies.
- Improve restoration time for enhanced System Average Interruption Duration Index (SAIDI) and Customer Average Interruption Duration Index (CAIDI).
- Eliminate or reduce repeated momentary faults.
- Improve repair times with reduced susceptibility to cascading failures.
- Locate precursors of equipment failure, so failing equipment can be removed before it fails.
- Provide information to operators on fault types based on waveform signatures.

**How to Apply Results**

Distribution system operators can integrate this system with their own monitoring and information systems to dispatch crews to estimated fault locations in near real time. The fault-location system includes fault location algorithms, interfaces to a variety of distribution modeling databases and monitoring equipment, and a user interface for operators.

**2012 Products**

<table>
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<tr>
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<th>Planned Completion Date</th>
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<tbody>
<tr>
<td>Fault Location &amp; Anticipation:</td>
<td>10/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

**P180.008 Reliability Practices and Drivers (070617)**

**Key Research Question**

Distribution reliability continues to be an important part of utility customer service, and regulators are increasingly using reliability as a measure of utility performance.

In a number of areas, further research could help members identify and implement noteworthy reliability practices, better manage reliability programs, and improve reliability, addressing questions such as:

- Is our hazard-tree program working
- Where can we best apply reclosers
- Can we show regulators the impact of a particularly severe storm season
- Where should we target investment money
- How do we compare with our utility peers
- What practices would be most effective in improving the reliability of our system
- Which practices best prepare our system for additional smart technology

**Approach**

This project identifies leading practices being employed industry-wide and provides guidelines for maintaining and improving reliability. EPRI will conduct "immersions," where EPRI resources reside on site at participating utilities to understand, identify, and document practices of note being employed to maintain and improve

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reliability. These practices will then be shared with other members to facilitate the identification of alternative approaches for improving reliability.

Impact

- Reduce customer interruptions (for example, System Average Interruption Frequency Index [SAIFI], Momentary Average Interruption Frequency Index [MAIFI]).
- Improve restoration times (for example, System Average Interruption Duration Index [SAIDI], Customer Average Interruption Duration Index [CAIDI]).
- Meet regulatory requirements more efficiently.
- Apply reliability improvement programs more efficiently.

How to Apply Results

Members can use the results of the project research to identify preferred methods for improving the reliability of their system, including refining existing approaches and applying new approaches.

2012 Products

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<td>Reliability Practices and Drivers:</td>
<td>07/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>This project identifies leading practices and guidelines for improving distribution reliability. The core activity of this research is the identification and documentation of leading practices for maintaining and improving distribution system reliability.</td>
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</table>

P180.009 Reliability Metrics and Special Topics (070618)

Key Research Question

There is an ongoing challenge to apply reliability metrics in ways that are more useful and provide a representation of system reliability performance that can be used to compare and benchmark performance effectively, while also providing the information necessary to prioritize investments.

Approach

EPRI will engage with experts from the IEEE 1366 Working Group of the Distribution Subcommittee in order to identify industry priorities for advanced statistical approaches and analytical methods that can be applied with reliability metrics to better characterize system performance. The project will also coordinate with the Cost/Benefit Framework for assessing smart grid projects developed by the DOE and EPRI. This work will focus specifically on characterizing the performance of smart grid investments in the area of reliability improvement.

Specific areas of work may include:
- Developing advanced approaches for weather normalization
- Assessing the benefits of specific automation investments on a feeder-by-feeder basis
- Effectively using data from outage management systems
- Assessing reliability metrics using advanced metering system data
- Using reliability metrics to assess vegetation management programs
- Defining metrics for evaluating the effectiveness of fault location and fault performance improvement
- Developing reliability benchmarks as a function of distribution system characteristics

Impact

- Better use of reliability metrics for characterizing system performance in ways that can be used for assessment of investment effectiveness
- Reliability metrics for evaluating smart grid investments
- More accurate and useful reliability metrics incorporating outage management systems (OMSs) and advanced metering infrastructure (AMI) data

**How to Apply Results**

Members will be able to apply these techniques directly to their own internal reliability metrics calculation systems.

**2012 Products**

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<td>Reliability Topics: This project will coordinate with the activities of IEEE 1366 to help advance the state of the art in calculating reliability metrics, adjusting for major events and applying normalization approaches to make the reporting more useful.</td>
<td>10/31/12</td>
<td>Technical Update</td>
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</table>

**PS180E Safety (070619)**

**Project Set Description**

This project set is focused on safety, and for 2012 the topics to be covered will be distribution arc flash and arc detection to enhance worker safety. The goal is to provide timely and relevant knowledge to members on issues related to these two topics. It is expected that this knowledge will enable members to take appropriate action immediately.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>P180.010</td>
<td>Distribution Arc Flash</td>
<td>There is an industry need to better evaluate many of the design, technology, and process options to reduce arc flash hazards. EPRI will coordinate with other industry groups, including the IEEE 1584 and the American Society for Testing and Materials (ASTM) working groups.</td>
</tr>
<tr>
<td>P180.011</td>
<td>Arc Detection and Contact Voltage</td>
<td>Advance Sensing Algorithms and Hardware: The project will provide state of the art insights into how to understand, measure and resolve safety related concerns for arcing and contact voltages</td>
</tr>
</tbody>
</table>

**P180.010 Distribution Arc Flash (070620)**

**Key Research Question**

There is an industry need to better evaluate many of the design, technology, and process options to reduce arc flash hazards. Arc flash hazard reduction and mitigation involve system protection and device coordination, equipment design and specification, work procedures, and protective clothing and equipment. Each of these aspects can play a role in reducing arc flash hazards. Although much research has been performed, some areas still need attention. Moreover, certain regulatory guidelines, including the National Electrical Safety Code (NESC) Section 410 and Occupational Safety and Health Administration (OSHA) 1910.269 and 1926 Subpart V, continue to evolve. This research will help guide that evolution and help utilities comply. Protective clothing has advanced significantly in the last decade, and further advances are expected. Ongoing work is needed to evaluate clothing performance in practical use and in arc flash scenarios that may be encountered by utility workers.
This project also supports a Distribution Arc Flash interest group. The interest group allows open exchange of information on practices with utilities. Session focus topics can include best ways to implement arc flash programs, specific work practices, clothing acceptability and performance, and specific application areas like secondary networks.

**Approach**

EPRI supplemental research work has provided the industry considerable experimental data on incident energies from a variety of arc flash hazards. EPRI will build on this and other research by coordinating with other industry groups, including the IEEE 1584 and the American Society for Testing and Materials (ASTM) working groups.

This project expands on earlier supplemental work to address the following:

- Case studies of approaches for addressing arc flash hazards
- Targeted testing of distribution-specific equipment (specific equipment to be determined)
- Testing of fabrics and clothing systems
- Development and reviews of improvement options

**Impact**

- Improved worker and public safety
- More efficient implementation of arc flash programs
- Validation of predictive modeling and simulation tools
- Better industry standards

**How to Apply Results**

Safety engineers can use the results to design and integrate safety programs. Protection engineers can improve coordination of protective relays and reclosers with arc flash hazards. Distribution engineers can apply new arc flash knowledge to work procedures.

**2012 Products**

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<td>09/30/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

**P180.011 Arc Detection and Contact Voltage (070621)**

**Key Research Question**

The state of the art in understanding and mitigating shock and other contact voltage–related concerns has evolved to the point where advanced diagnostics technologies can be used to better understand and resolve virtually any concern type. The objectives of this research are to conduct research and field tests that produce more practical diagnostics technologies and algorithms that improve public and worker safety—and may in certain cases improve system reliability. While continuing to support traditional stray voltage regulatory and standards development issues, this project will focus on more advanced technology development over the next several years.
Approach
This collaborative research project provides the latest techniques for understanding and dealing with virtually all related concerns at readily accessible human and animal contact locations. The main goal of the project in 2012 is to utilize new technology to more readily understand source and coupling mechanisms for arc detection and the more traditional for contact and stray voltage. These technologies include handheld electric field sensors and a mobile diagnostics platform that combine low- and high-frequency data acquisition in real time. The goals are to develop a suite of diagnostics technologies that make it easier to locate, remediate and understand contact voltage sources such as high impedance and open neutrals and a multitude of other concerns. In addition, the wealth of material developed in prior years will be maintained on the contact voltage website to support staff training, industry awareness, regulatory inquiries, and overall understanding of related subjects.

Impact
- Lower the risks and costs of potential problems, providing savings on future engineering investigations by providing evaluation methods and field-proven solution methodologies.
- Reduce the possibility of humans and animals experiencing perceptible levels of elevated voltage.
- Enhance members’ ability to comply with existing or anticipated regulatory limits related to stray voltage.

How to Apply Results
Project members can use this work to develop comprehensive methodologies and processes for handling customer complaints and regulatory inquiries about elevated neutral to earth (NEV) and urban stray voltage; prioritize and standardize the means by which members repair or provide mitigation solutions for identified voltage concerns and how they support customer-initiated remediation; and develop training tools and standardized investigation procedures for their staff that result in a well-defined, structured process from the initial complaint to final follow-up.

2012 Products

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<tr>
<td>Advance Sensing Algorithms and Hardware: The project will provide state of the art insights into how to understand, measure and resolve safety related concerns for arcing and contact voltages.</td>
<td>07/31/12</td>
<td>Assembled Package</td>
</tr>
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</table>

PS180F Smart Distribution Applications (070622)

Project Set Description
This project set develops and evaluates advanced distribution system applications for reliability improvement, system optimization, asset management, and distributed resource integration. These applications involve implementation of monitoring equipment (sensors), communications infrastructure, and advanced protection and control functions. The program will support utilities in the migration to distribution management systems with model-based management of the system. The Distribution Management System (DMS) of the future will need to integrate many functions to optimize system performance, reduce losses, optimize voltage and VAR control, improve reliability through system reconfiguration and fast restoration, and integrate distributed resources. The project set builds on the analytical capabilities of the Open Distribution Simulator Software (OpenDSS) software for analytical assessment of advanced distribution management functions and also works with member utilities to demonstrate advanced functions for development of application guidelines and identification of gaps in the technologies.
The project set will also support a Distribution Management System Interest Group. This interest group will provide an information sharing forum for development of requirements for DMS implementations, sharing experience from actual implementations, and brainstorming for future applications. Gaps identified will help EPRI in prioritizing future research in this project set.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>P180.012</td>
<td>Distribution Management Systems Planning Guide</td>
<td>This project will provide guidelines and detailed information needed to plan for distribution management system (DMS) implementation. The project includes criteria (an &quot;opportunity matrix&quot;) for selecting DMS applications to address important business drivers, functional descriptions of key applications, guidelines for identifying a generalized (conceptual) architecture, implementation and sustainment strategies, and other important information.</td>
</tr>
<tr>
<td>P180.013</td>
<td>Benefit Cost Analysis for Smart Distribution Applications</td>
<td>This project includes development of a software tool (an Excel spreadsheet) for analyzing the costs and benefits of smart distribution applications. Program users will be able to select smart applications of interest, enter required data (application-specific parameters, distribution system data, financial information, unit cost estimates), and obtain outputs such as analysis of revenue requirements, benefit cost ratio, payback period, return on investment, and other information needed to determine the economic justification for smart distribution investments.</td>
</tr>
<tr>
<td>P180.014</td>
<td>Smart Distribution Applications for Distributed Energy Resources</td>
<td>This project will include an in-depth investigation of smart distribution applications for monitoring and controlling distributed energy resources (DERs) (distributed generation, including renewables, and energy storage). The expanded role of DERs in volt-VAR optimization, reliability improvement measures, system reconfiguration, microgrid operation and control, and other DA/DMS applications will be explored.</td>
</tr>
</tbody>
</table>

**P180.012 Distribution Management Systems Planning Guide (070623)**

**Key Research Question**

As electric utilities embark on a plethora of new smart grid projects to develop and deploy new technologies on their electric distribution systems, they face numerous organizational challenges. The smart grid will provide a wealth of new information and many new intelligent controllers and control schemes that will enable electric utilities to improve the performance, reliability, efficiency, and safety of the electric distribution system. To enable the distribution system operators or dispatchers to effectively manage these systems and information, the control center needs to become much “smarter.” One of the key elements of the new smart control center is the distribution management system (DMS).

Transitioning from mostly manual processes for managing and operating the electric distribution system to automated processes requires careful planning and a well-thought-out strategy. This project will provide a methodology for developing a detailed plan for DMS implementation.

**Approach**

This project uses the results of the DMS Interest Group (DMSIG) as a foundation for the proposed deliverable. To be successful, the DMS must support important business drivers and objectives established by the individual electric utilities. The proposed methodology will describe processes for identifying these important business needs and then translating the business needs into the DMS requirements. An “opportunity matrix” will be provided to aid in translating business needs to appropriate DMS applications. The project will provide functional descriptions of the major application functions and will also supply guidelines for selecting a “conceptual” architecture for the system (centralized scheme versus decentralized application). This information will lay the...
foundation for developing more detailed specifications that a utility needs to procure the hardware, software, and services necessary to procure, install, and commission the DMS. The proposed planning guide will also include budgetary and scheduling guidelines, list of required resources, installation guidelines, and information on making the transition to DMS-based operations.

**Impact**

- Provide a foundation for implementing voltage optimization systems as a function of distribution system characteristics and existing infrastructure.
- Provide tools for assessing voltage optimization performance at the design stage (support of business case development).
- Provide field experience from actual implementations.
- Identify new functionality that can improve the performance of voltage optimization systems.

**How to Apply Results**

Members will use the results to help specify voltage optimization systems as part of overall smart distribution development, develop the business cases for voltage optimization functions, and evaluate performance of systems being implemented.

**2012 Products**

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Distribution Management Systems Planning Guide</strong>: This report will provide guidelines and</td>
<td>11/30/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>detailed information needed to plan for distribution management system (DMS) implementation. The project includes criteria (an “opportunity matrix”) for selecting DMS applications to address important business drivers, functional descriptions of key applications, guidelines for identify a generalized (conceptual) architecture, implementation and sustainment strategies, and other important information.</td>
<td>11/30/12</td>
<td>Technical Update</td>
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</table>

**P180.013 Benefit Cost Analysis for Smart Distribution Applications (070624)**

**Key Research Question**

A major obstacle to deploying smart distribution applications is lack of economic justification. Some smart distribution applications require a substantial investment of technical and financial resources; therefore, it is important to determine if the benefits achieved outweigh the investment total cost of ownership. Many of the benefits provided by the smart distribution applications do not translate easily into monetary terms; consequently, cost–benefit comparisons can be difficult to perform. For example, the application “Fault Location Isolation and Service Restoration” provides significant improvement in customer outage duration. However, there is no well-established procedure for converting improved reliability to direct monetary benefits to determine if these benefits outweigh the high implementation cost for this application. EPRI will perform the necessary research to develop algorithms to compute the benefits and costs of each application.

Without a clear understanding of the business case, an electric utility may not be able to proceed beyond a limited scale demonstration project.

The proposed software tool will help electric utilities make informed decisions as to whether the benefits of smart distribution applications outweigh the costs.
**Approach**

EPRI plans to develop an Excel spreadsheet that will enable electric utilities to perform a benefit cost analysis to determine if smart distribution benefits outweigh the costs. The spreadsheet will include facilities to enable electric utilities to select the application functions of interest and enter the technical and financial information needed to compute benefits and costs. Outputs will include an analysis of revenue requirements, benefit cost ratio, payback interval, return on investment and other economic indicators.

The program inputs will include items that are readily available at most utilities. Suitable default values will be provided where possible.

**Impact**

The project results will provide the resources for needs assessment, business case development, and specification of advanced system reconfiguration functions that could be implemented as part of a distribution management system including:

- Performance assessment for advanced reconfiguration functions
- Benefits that can be achieved with advanced reconfiguration functions
- Requirements for advanced reconfiguration functions

**How to Apply Results**

Members will use the results to help determine the economic justification for smart distribution expenditures.

**2012 Products**

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<tbody>
<tr>
<td>Benefit Cost Analysis Software Tool for Smart Distribution Applications:</td>
<td>12/31/12</td>
<td>Software</td>
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</table>

**P180.014 Smart Distribution Applications for Distributed Energy Resources (070625)**

**Key Research Question**

This project will include an in-depth investigation of smart distribution applications for monitoring and controlling distributed energy resources (DERs) (distributed generation, including renewables, and energy storage). The expanded role of DERs in volt-VAR optimization, reliability improvement measures, system reconfiguration, microgrid operation and control, and other Distribution Automation (DA) and DMS applications will be explored.

**Approach**

This project will evaluate the application of advanced monitoring and control functions for DERs that accomplish multiple objectives. The potential to integrate DERs into volt-VAR optimization, system reconfiguration (including microgrids), and other applications will be explored. The approach will involve implementation of models for the basic functionality of DERs monitoring and control systems. The models will be applied for different distribution system characteristics, load characteristics, and fault profiles. Using models to evaluate performance issues will permit development of basic requirements for these systems and assessment of the potential benefits without
actually deploying systems in the field. The result of the analysis will be an assessment of requirements and expected benefits of advanced reconfiguration functions.

Impact
- Members will gain insight into new distribution functions and operational benefits that can be derived from advanced metering infrastructure (AMI) investments through characterization of important distribution applications and their associated requirements.
- Business cases for advanced metering that rely on distribution operations benefits as part of the plan will be more accurate.
- Members can develop accurate implementation and deployment plans for distribution operations functions that are built on AMI investments.

How to Apply Results
Members will be able to better plan investments in smart distribution applications through an understanding of application requirements and performance under different circumstances. Members will be able to use the OpenDSS software as a platform for evaluating advanced applications for their own distribution systems. Example applications will provide templates for these evaluations. Members will be able to assess the economics and benefits of different applications as a function of their implementation costs.

2012 Products

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<td><strong>Smart Distribution Applications for Distributed Energy Resources:</strong> This report will include an in-depth investigation of smart distribution applications for monitoring and controlling distributed energy resources (DER) (distributed generation, including renewables, and energy storage). The expanded role of DER in volt-var optimization, reliability improvement measures, system reconfiguration, microgrid operation and control, and other DA/DMS applications will be explored.</td>
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<td>Technical Update</td>
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</table>

PS180G Technologies Evaluation & Assessment (070626)

Project Set Description
This project set evaluates and assesses new technologies for smart distribution systems that could become an integral part of the future distribution infrastructure. The rigorous unbiased evaluation and assessment methodology includes laboratory-specified testing combined with practical field experience to produce fact-based results.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P180.015</td>
<td>Sensors</td>
<td>This project will research and evaluate sensor technologies for current and voltage monitoring, as well as equipment diagnostics and asset management methodologies. It will also investigate the key considerations involved and possible implementation methodologies for the development of a valuable and successful integrated condition monitoring program.</td>
</tr>
<tr>
<td>P180.016</td>
<td>Advanced Meters</td>
<td>This project will use a combination of laboratory and field testing to characterize application issues and develop lifetime characteristics of advanced metering equipment.</td>
</tr>
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</table>
**P180.015 Sensors (070627)**

**Key Research Question**

Sensors are fundamental to distribution network state estimation, which is fast becoming a prerequisite for smart grid functionality. Transition from a passive to an active distribution network through condition monitoring allows for improved performance and flexibility of network operation as it:

- Provides self-healing capabilities to improve or maintain quality of service and reduce costs
- Increases the capacity of the grid to host distributed generation
- Defers investments and keeps up with possible higher load demands
- Improves asset management decisions

Other drivers for deploying an active monitored investment include assuring security of supply, system safe operation, and environmental compliance. Monitoring extensive distribution systems is challenging due to the investment associated with the deployment and maintenance of sensors and the scale of the resulting data. Sensing technologies should be low cost to allow widespread deployment, and must incorporate communications to allow integration with the smart distribution system infrastructure.

This project will research sensor technologies and infrastructures for the management of electricity distribution networks considering all the above factors.

**Approach**

This project is based on a multi-year plan designed to provide short-term benefits to members as well as perform more fundamental research to take advantage of new learnings and developments with the experience and knowledge established from previous years. In 2012, this project builds on preliminary work conducted through EPRI's Technology Innovation initiative to characterize a variety of sensor technologies that could become part of the smart distribution system in both overhead and underground applications. The work will focus on the cataloguing and assessment of current industry practices and procedures. It will also perform research into other available sensor technologies presently under development or in use outside the electricity industry. The project will conduct actual field assessments of new sensor and transducer technologies with integrated communications.

**Impact**

Improving energy efficiency requires the grid to minimize energy delivery losses and perform in a proactive manner in order to most optimally balance supply with demand. With the increased performance expectations of the modern distribution network, accomplishing this task requires a form of intelligence on the grid that to date has not been available or necessary. The absence of an economical sensing and communications infrastructure that parallels the electrical infrastructure poses one of the largest challenges facing the electric distribution system.

This project will help members with the following:

- Understanding and assessing the performance of new sensor technologies that can be part of smart distribution systems
- Development of application guidelines for new sensor technologies
- Enabling integration of new sensor technologies with overall distribution management systems

**How to Apply Results**

- Members will gain an understanding of new sensor technologies.
- Members will understand the benefits and limitations of important new sensor technologies and will receive application guidelines from actual field experiences.
• New sensor technologies must be integrated with overall distribution management systems and can provide the basis for new real-time system performance optimization. This project will research and document methodologies to help achieve this.
• Members will get a head start on developing and implementing these advanced applications through documentation of sensor functionality, accuracy, and applications

2012 Products

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<tr>
<td>Sensor Database: This database will allow members to rapidly comprehend the full spectrum of options available and make efficient and effective implementation decisions. It will contain information that catalogs and categorizes available technologies and unbiased test results.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td>Guide of Sensor Technology Application Practices: This report will contain methodologies for successful implementations of sensing technologies.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>

P180.016 Advanced Meters (070628)

Key Research Question

Many utilities are in the process of evaluating and deploying advanced solid-state meters. These technologies have been in limited use for many years, but are now being rolled out in large numbers as AMI deployments drive wholesale meter replacements. However, utilities still have limited experience with these products, and important questions remain regarding reliability, robustness, and functionality. Utilities need to understand important field applications, life cycle characteristics, and the technology's ability to withstand a wide range of environmental stress conditions.

Approach

This project focuses on evaluating meter products and application issues that will become part of the smart distribution system. It will use a combination of laboratory testing and actual field performance assessments to develop conclusions about advanced meter capabilities and lifetime characteristics. This research has a number of important components:

• Environmental testing in the laboratory. This project will use accelerated lifetime tests to understand the ability of solid state meters to withstand environmental conditions over the long term.
• Abnormal voltage and current testing in the laboratory. This project includes testing the communications interfaces for the meters as well as voltage and current monitoring performance under adverse conditions.
• Characterization of the effect of harmonics and power factor on meter accuracy. Future meters may need to characterize customer impacts on harmonic distortion and power factor. This feature will require the ability to characterize customer load and generation accurately for both fundamental and harmonic conditions. Laboratory testing will characterize meter performance for non-sinusoidal conditions and for characterizing load power factor.
• Evaluation of important field application issues and performance through experience with initial advanced metering deployments.
• Advanced meters will need to continue to operate during power outages to provide functionality for smart distribution systems (for example, integration with outage management systems). The project will evaluate super capacitor battery performance and meter performance during and after outages.
Impact

- Understand new application and issues for advanced meters as they are integrated with smart distribution systems.
- Understand the expected lifetime for solid-state meters for planning and budgeting of maintenance and replacement plans.
- Understand the performance of solid-state meters during transients and for characterizing harmonics and power factor. These could be important functions in the smart distribution system.
- Understand the impact of integrated communications with advanced meters on application issues (such as lifetime, maintenance requirements, and installation issues).

How to Apply Results

- Members will be able to develop more accurate budgets and plans for advanced meter deployments.
- Members will be able to develop better plans for integrating advanced meters with smart distribution systems by understanding important application issues and meter limitations.

2012 Products

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<tr>
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<tbody>
<tr>
<td><strong>Solid State Meter Accuracy in the Presence of Low Frequency Conducted Signals:</strong> A number of new technologies, including electric vehicle chargers, photovoltaic inverters, and compact florescent lighting, are generating new and increased sources of noise on customer power systems. This project will perform extensive laboratory evaluation of the ability of solid-state meters to perform accurately in the presence of these signals.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>

PS180I Distribution Systems Practices (070632)

Project Set Description

This Project Set focuses on overhead and underground distribution system practices, with the intent of capturing and documenting leading utility practices for all functional areas. Participating members can expect to measure, compare, and validate their current practices and determine if any are in need of adjustment. By identifying better methods, utilities can improve efficiency, reliability, and safety.

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<tr>
<th>Project Number</th>
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<th>Description</th>
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<tbody>
<tr>
<td>P180.019</td>
<td>Underground Practices</td>
<td>This project focuses on identifying and collecting leading underground distribution systems key functional practices.</td>
</tr>
<tr>
<td>P180.020</td>
<td>Overhead Practices</td>
<td>This project focuses on identifying and collecting leading overhead distribution systems key functional practices.</td>
</tr>
</tbody>
</table>

P180.019 Underground Practices (070633)

Key Research Question

Underground systems are a crucial part of the industry and deliver high levels of reliability and customer service. However, underground systems also present challenges, such as high costs for construction and maintenance, and require unique skill sets for effectively managing urban network systems, typically held by a few key individuals. Moreover, the loss of experienced engineering staff to mergers and attrition has left many utilities with a gap in the expertise needed for optimal planning, design and engineering, construction, and operation and maintenance of urban underground and network systems.
Approach
This project focuses on urban underground distribution systems and uses a research approach where an EPRI project team visits a utility and immerses itself in the utility operation, collecting practice information firsthand from utility planners, engineers, operators, and field work crews. The research results are published in reports that summarize key practices and are populated in an online dynamic industry data repository. The data repository enables research participants to identify, analyze, and compare peer company approaches to managing urban underground distribution systems.

Impact
- Improve the reliability of underground distribution systems through the identification and application of alternative, optimal reliability practices.
- Improve the safety of utility activities involving construction and operation of underground systems through the identification and application of alternative, optimal safety practices.
- Improve the efficiency associated with planning, designing, engineering, constructing, and operating distribution systems through the identification of alternative, optimal management practices.

How to Apply Results
Members can use the leading practice database to perform in-depth peer-to-peer comparison of current practices to identify optimum methods to manage their underground systems.

2012 Products

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<tbody>
<tr>
<td><strong>Urban Network Practices</strong>: This Technical Update report will summarize practice findings.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Urban Network Practices Survey</strong>: EPRI will conduct an industry survey of urban network practices. The results will be issued as a technical update.</td>
<td>09/30/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Urban Network Practices Repository</strong>: Practices will be incorporated into a data repository to facilitate comparison and analysis by research participants. Updates to the repository will be issued as a technical update.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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**P180.020 Overhead Practices (070634)**

Key Research Question
Overhead distribution systems represent the largest percentage of the industry asset base and are built to many different standards and in many different ways. A fresh look at the typical functional overhead practices is needed on an industry scale. The loss of experienced engineering staff and field construction expertise to mergers and attrition has left many utilities with gaps in planning, design and engineering, construction, and operation and maintenance of overhead systems.

Approach
This project focuses on overhead distribution systems, using a research practice where an EPRI project team visits a utility and collects practice information firsthand from utility planners, engineers, operators, and field work crews. The research results are published in reports and populated in an online dynamic industry database tool. The tool enables utility peer-to-peer comparison and analysis.
Impact

- Improve the reliability of overhead distribution systems.
- Improve the safety of utility activities involving construction and operation of overhead distribution systems.
- Reduce the costs associated with planning, designing, engineering, constructing, and operating overhead distribution systems.

How to Apply Results

Members can compare and contrast their current practices with their industry peer group.

2012 Products

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<tr>
<td><strong>OH Lineworker Practices:</strong> This Technical Update report will summarize the practices identified through practices immersions conducted in 2012.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>OH Practices Repository:</strong> Practices summaries from immersions will be populated into a data repository and issued to research participants as a technical update.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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PS180J Tech Transfer and Industry Coordination (070635)

Project Set Description

The Distribution Technology Transfer and Industry Coordination project set is designed to provide utilities with high-impact resources that cover topics relevant to distribution systems and to keep members up to date on the latest technology advancements and industry issues.

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<tr>
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<th>Description</th>
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<tbody>
<tr>
<td>P180.021</td>
<td>Tech Transfer and Industry Coordination</td>
<td>EPRI's distribution knowledge-based services cost-effectively support utility distribution engineering managers and staff with technical resources, training, and standards information.</td>
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</table>

P180.021 Tech Transfer and Industry Coordination (070636)

Key Research Question

Distribution companies face a variety of pressures and technical challenges. Utility planners, engineers, and operators must stay familiar with the latest technologies, software tools, standards, and procedures for optimizing distribution system performance. At the same time, many utilities are losing valuable experience as the aging workforce retires.

Approach

EPRI’s distribution knowledge-based services cost-effectively support utility distribution engineering managers and staff with technical resources, training, and standards information. Members gain access to the best distribution engineering expertise in the industry to deal with specific challenges in a timely manner and stay informed on key technical developments. The project includes the following:

Conferences: IEEE Power Meetings, CIRED conferences, and other important conferences will be summarized for members to increase awareness of important developments.

Distribution Hotline Access: Members will have access to a distribution hotline, gaining quick-response access to EPRI's power system experts to help answer technical questions related to distribution engineering, operations, and maintenance.

Member Forum: Members can participate in a web-based forum, with topics covering any issue related to distribution system design and operations, such as equipment problems, maintenance strategies, application of equipment, and reliability problems.

Impact

- Increase the productivity and technical expertise of staff.
- Represent members' interests with respect to standards development.
- Provide cost-effective and timely updates on industry developments.

How to Apply Results

Utility managers and staff can immediately use the knowledge provided by this program to improve distribution system design, maintenance, and troubleshooting practices. The service is provided through a member forum, which allows for easy access to knowledge, discussions, and expert staff.

2012 Products

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<tr>
<td><strong>Hotline</strong>: Members gain access to the best distribution engineering expertise in the industry to deal with specific challenges in a timely manner and stay informed on key industry technical developments.</td>
<td>12/31/12</td>
<td>Technical Resource</td>
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Supplemental Projects

Hybrid Transformer Demonstrator (072113)

Background, Objectives, and New Learnings

The ever-increasing expectation for efficient, reliable energy to power today’s digital economy has undoubtedly challenged the suitability of the existing ac system. Today’s distribution system is expected to supply power to loads for which it was not designed. Moreover, high penetration of distributed generation units is redefining the requirements for the design, control, and operation of the electric distribution system. Globally, the electric power industry has turned toward smart grid–enabled equipment installed on distribution systems. “Smart grid components” are components with microprocessor-based controllers that can communicate with a master controller. These components either control power flow or power quality in the network. In addition smart grid technologies can enable the large-scale integration of renewable generation needed to meet the rising demand for electricity from low-carbon sources.

Project Approach and Summary

EPRI, in collaboration with the ABB Group plans to demonstrate a power-electronics-enhanced transformer (hybrid transformer), based on a conventional transformer and a power-electronics active voltage conditioner (AVC). The hybrid transformer is expected to provide more functionalities than simply voltage transformation and galvanic isolation and will be demonstrated in three phases:

- In the first phase of the project, the hybrid transformer will be capable of continuous ±10% voltage regulation and communication with a central control center.
- The second phase is planned to incorporate VAR compensation capability onto the same power platform. Studies to determine the technical and market requirements for VAR compensation will be conducted in this phase.
- Finally, the third phase of the project will study the requirements for the integration of energy storage systems with the hybrid transformer.

Benefits

The device will encompass all the necessary technical features that will allow testing of the control capabilities on a component and system level at the host site. Working closely with utilities will aid in developing a commercialization strategy for the hybrid transformer.
**Arc Flash for Medium-Voltage Equipment (072114)**

**Background, Objectives, and New Learnings**
EPRI has had a series of projects on distribution arc flash. One of the most consistent findings is that arc flash is equipment specific. Energies depend strongly on electrode configurations and enclosure geometries. One of the most surprising results was from tests on a medium-voltage pad-mounted switch that produced incident energies three times higher than predicted by IEEE 1584 models. This particular switch had a bus configuration that focused the arc and fireball out the front of the enclosure in the direction where a worker would be standing.

The main objective of this project is to test more equipment and use results to develop arc flash models for that equipment. We plan to share results with the IEEE 1584 Working Group to help it improve future versions of the *IEEE Guide for Performing Arc Flash Hazard Calculations*.

**Project Approach and Summary**
The main work will involve testing equipment at a high-current laboratory. Tests will be instrumented with calorimeters and high-speed cameras to allow us to capture more data on the physics behind arc flash events.

**Benefits**
This project should help utilities implement better arc flash programs. Results will help utilities to coordinate protective clothing, relaying, and work practices.

Testing will help to answer several questions on arc flash in gear:
- Do existing IEEE 1584 models accurately predict energy in real gear
- How much energy is blocked by the circuit breaker for a fault in the back of the switchgear
- How does the incident energy change with equipment size and bus spacings
- How does the incident energy vary with time
Cable Validation for Fleet Management (072115)

Background, Objectives, and New Learnings
Reliability and fleet management of underground cable systems begin at the most fundamental level with ensuring that quality products are procured from approved vendors. The quality of cables has steadily improved over the years as a result of enhanced testing requirements in industry standards. However, mistakes are still made in manufacturing processes, and pressures for profitability in the marketplace can adversely impact product quality. In addition, new lower cost suppliers enter the market with little or no performance history. New Learnings will include statistical analysis and validation of the quality of products sourced from long-standing domestic sources as well as new market entrants from outside the United States.

Project Approach and Summary
This project will provide testing, quality validation, and statistical analysis of materials to ensure that only the highest quality materials are placed in service. Tasks may include sample testing, full reel testing, plant quality audit support, statistical analysis, and trending of data versus a database of industry suppliers. Testing and inspection of materials at the manufacturing plant or sample testing prior to delivery ensures that the product meets the utility’s raw materials and purchasing specifications. Applicable industry standards for production of quality cables include:

- ASTM B-8
- ASTM B-231
- ANSI/ICEA S-94-649
- AEIC CS-8
- RUS U-1

Benefits
This research will benefit the public through reduced outages by ensuring that only high quality materials are installed. Participants will benefit from the validation of quality incoming cables to ensure system reliability, cable fleet performance, and reduced overall cost. Members will have access to the growing EPRI database of cable fleet management statistics and practices.
Distribution Robotics (072116)

Background, Objectives, and New Learnings

A number of considerations make robotics a viable option for distribution systems applications in the overhead and underground areas. Overhead Line workers are often exposed to inclement weather, strenuous work conditions, heights, and heavy machinery. Underground Line worker entering structures can be exposed to risks including electrical discharges, heat, gases, moisture, and cramped conditions.

Specifying, developing and applying novel and unique robotics during routine operations, to perform environmental safety assessments, eliminating dangerous electrical conditions, and performing damage assessment, will be invaluable. Cost-effective robotic solutions need to be developed where they can increase the safety, productivity, and comfort of employees.

The project aims to develop functional specifications and prototypes for a selection of robotics technologies for safer, more effective work on distribution systems. The work will be scoped such that separate efforts will address the underground and overhead areas.

Project Approach and Summary

A platform of technologies will be investigated for robotics that can be applied to both overhead and underground distribution systems. The goal is to build and demonstrate prototype robots using a disciplined research method whereby functional specifications are first documented and development follows.

The potential of aerial vehicles (fixed wing manned and unmanned) to inspect/assess and assist with damage assessment of infrastructure is unknown. Enabling rapid damage assessment will allow electric power companies to reduce restoration time. EPRI will define the functional requirements necessary to perform aerial assessment and data collection.

Underground Systems: Use of remote controlled robotics.
Underground structure entry and work can be accomplished more safely when done by a robot under remote control. Remote operations eliminate worker exposure to confined space hazards, and this technology application will improve many facets of asset ownership. Adding visual technologies will improve consistency on decisions regarding structural integrity by allowing additional experts to remotely view a structure from their office while crews are at the inspection location.

Benefits

For overhead distribution systems, wide scale inspection and assessment through the use of aerial vehicles will dramatically improve overall asset management and when used for storm damage can reduce restoration and recovery efforts.

For underground distribution systems a structure entry and work robot will be researched. A manhole inspection robot should help utilities perform safer, more effective manhole and vault inspections. Robots may also be developed to improve other manhole work.
Occupational Exposure to Physical Stressors (072036)

Background, Objectives, and New Learnings

Occupational exposures to physical stressors such as noise are prevalent within the electric utility industry. During 1995-2009, the EPRI Occupational Health and Safety Database, which tracks illness and injury for eighteen member utilities, showed that hearing loss or impairment resulted in 3% of total utility worker injuries. If constantly exposed to noise, workers may experience progressive hearing loss slowly over time, which in turn may affect their ability to perform safely and translate to an indirect number of acute workplace injuries.

Noise-induced hearing loss has been implicated in workplace accidents. Auditory changes are progressive, possibly placing workers at risk for accidents. Traditionally, workers are enrolled in hearing conservation programs after an action level of 85 decibels (dB) is met. Noise surveys capture environments requiring action but are not conducted at multiple time points; consequently, noisy environments may be underestimated. According to published studies in the aluminum industry, annual audiometry data capture hearing loss once it has occurred and the most vulnerable workers actually may fall below the accepted permissible exposure limit. Since opportunities to intervene prior to hearing loss are limited using annual audiometry, data gaps exist for workers who may be just below 85 dB and who may potentially have preventable workplace hearing loss.

Workers may use personal protective gear such as ear muffs and ear plugs that modify exposure; hence, measured ambient or personal exposure levels may not reflect actual exposure. Novel in-ear dosimetry technology—devices that fit like an earplug and measure attenuated noise from within the ear canal—could be used to address worker discomfort and potential exposure modification issues. In addition, the dosimeter could be programmed to advise the worker and/or her/his supervisor when pre-set exposure limits are exceeded. Thus, a worker would get feedback on exposure above that pre-set limit and on her/his daily dose at the end of the shift, both of which could assist in guiding personal protective equipment use.

Project Approach and Summary

In this project, research will evaluate the dosimeter using built-in feedback systems as an intervention method for preventing noise-induced hearing loss and will examine the relationship between noise levels and risk of acute occupational injury. Results will provide quantitative noise dosimetry, an assessment of the dosimeter as an intervention method and a potential leading indicator for noise-induced hearing loss and other injuries. By the end of the project, results should provide a method for assessing a state-of-the-art intervention method and an assessment of noise-induced hearing loss as a leading indicator for a number of acute workplace injuries.

Benefits

Workplace injuries are traditionally targeted using interventions proximal to the acute event, such as behavioral factors, rather than distal factors, such as other exposures. Furthermore, hearing loss is often attributed to workers’ lack of compliance, lack of supervision, or inappropriate use of personal protective equipment. This project assesses a potential leading indicator, not only of hearing loss, but also of workplace injuries. The developed intervention, if successfully applied, may result in reduced frequency of hearing loss and occurrence of acute injuries in the workforce, with associated potential cost savings and improved worker health and performance.

Occupational hygienists, managers, and safety specialists within electric utilities may use the in-ear dosimeter as a means to train their workers on the effective use of hearing protection and to clarify whether workplace noise is a contributor to other occupational injuries. Additional benefits derived from the work include an improved method to comply with OSHA “Employee Notification” requirements (1910.95).
Electric Transportation - Program 18

Program Overview

Program Description
The commercial rollout of plug-in hybrid and battery electric vehicles started in late 2010 and several major automakers have launched production plug-in vehicles (PEVs). The market introduction of PEVs presents electric utilities with many different challenges and opportunities. Aggregate projections of market adoption indicate that PEVs could exceed 5% of new vehicle sales by 2020 and large utilities could have hundreds of thousands of vehicles connected to their system for recharging, representing hundreds of megawatts of new demand. At the same time, transportation electrification will deliver annual CO2 reductions that could exceed 100 million tons by 2025 and 500 million tons by 2050.

Utilities need to understand the system impacts and customer requirements due to plug-in vehicles while conducting the necessary preparations to support the rollout and adoption of PEVs by their residential, commercial, and industrial customers. Electricity is the only potential energy source for transportation that addresses the simultaneous need for fuel diversity, energy security, reductions in greenhouse gas emissions, and improvements in air quality that is widely available and produced domestically. Electric utilities must understand the paradigm shift that will occur with an inevitable transition of transportation energy from petroleum to electricity—as well as their new role as a fuel provider for vehicles.

Nearly all of the major automakers are reaching out to the utility industry to develop and standardize infrastructure for recharging plug-in hybrids.

Fleets can offset high fuel costs and meet environmental requirements by incorporating plug-in hybrid or battery electric vehicles into operations.

Adoption of non-road electric vehicles at customer sites can reduce fuel costs and increase customer satisfaction. Emission-constrained sites like seaports and airports can reduce the cost of environmental compliance.

Research Value
The Electric Transportation program conducts research and development on vehicle and infrastructure technologies that enable the use of electricity as a transportation fuel. The program has played a leading role in the development of plug-in electric vehicle (PEV) technologies that are at the forefront of automotive industry development efforts. The Electric Power Research Institute (EPRI) also serves as a focal point of collaboration between the automotive and utilities industries for the development of infrastructure standards, vehicle demonstration programs, and advanced charging technologies. EPRI's non-road electric transportation efforts have demonstrated the cost-effective use of battery electric vehicles in numerous commercial and industrial applications and serve as the technical foundation for successful, customer-focused utility non-road electric transportation market expansion programs.

Approach
EPRI research in electric transportation will yield a variety of data and knowledge that will be beneficial to members of the program. This information will come in a number of forms and is expected to include the following:

- Formation of major collaborative PEV programs with the automotive industry, including General Motors, Ford Motor Company, and Eaton Corporation
- Analysis of potential impacts to utility systems
- Development of advanced charging technologies that enable integration of PEVs to the utility smart grid
Development of non-road electric transportation programs through field demonstration and technology development and assessment
Validation of the economic and environmental benefits (including greenhouse gas emissions) of PEVs to the utility, utility customers, and their communities
Utility-specific analyses on potential PEV market size, load shape and requirements, customer expectations, infrastructure requirements, and other material required to support internal utility PEV readiness or mainstreaming programs

Accomplishments
The electric transportation program has delivered valuable information that has helped its members and the industry in numerous ways. Examples include the following:

**On-Board Smart Charging Requirements for PHEVs—Product ID # 1015877**
The first plug-in electric vehicles (PEVs) started production in late 2010. Both vehicle owners and utility companies would benefit if PEVs could draw power during off peak periods, but implementing a demand response program will require grid-to-PEV bidirectional communications to allow the utility system to influence the timing and amount of energy the PEV draws from the grid. This report defines the technology needed for such "smart charging" and reviews the current status of the initiatives underway to accomplish it.

**Smart Charging Development for PHEVs—Preliminary Use Case Development for SAE Recommended Practice J2836—Product ID # 1015886**
This technical update covers the complete set of functional requirements for integrating plug-in electric vehicles (PEVs) into the smart grid, along with the utility programs they will be able to participate in and a vision for getting these requirements into standardized implementations. The document will help utility and original equipment manufacturer (OEM) staff gain a complete understanding of how they should go about developing PEV-utility requirements that will support programs for demand response and energy efficiency through their automated metering infrastructure.

**Impact of Plug-in Electric Vehicle Technology on Electricity Infrastructure, Preliminary Analysis of Capacity and Economic Impacts—Product ID # 1016853**
This report covers the evaluation of macro-level grid capacity impact of plug-in electric vehicles (PEVs) over the next two decades. The document covers both the EPRI Prism base case of 30% PEVs in 2030 and a more realistic penetration scenario that results in about 6% PEVs in 2030, mimicking the growth rate of hybrid-electric vehicles in the last decade. Also evaluated is the impact of the smart grid on load shifting and economic benefits in terms of deferred capacity investment.

Current Year Activities
- Develop framework for utility electric transportation readiness programs
- Conduct major utility field demonstrations of prototype and production PEVs to acquire and analyze vehicle, customer, and charging infrastructure test data.
- Develop and demonstrate vehicle and infrastructure charging technologies for "smart charging"
- Develop codes and standards for PEV communication to the electric grid and for direct current fast charging
- Demonstrate advanced electric-drive technologies in non-road applications

**Estimated 2012 Program Funding**
$5.0M

**Program Manager**
Mark Duvall, 650-855-2152, mduvall@epri.com
Summary of Projects

**PS18A Plug-In Electric Vehicle Development (056053)**

**Project Set Description**

This project set addresses the technologies and products that demonstrate the value of electric-drive systems and components in plug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV) applications.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P18.001</td>
<td>Plug-in Hybrid Electric Vehicle Evaluation and Test Data Analysis</td>
<td>This project provides a comprehensive real-world test program for PEV demonstration fleets using sophisticated systems for collecting and processing detailed vehicle information and reporting the results to members.</td>
</tr>
<tr>
<td>P18.003</td>
<td>Advanced Battery and Powertrain System Development for Plug-In Vehicles</td>
<td>This project will promote the development of Li-ion battery systems technologies and electric-drive powertrain systems technologies for PEVs, as well as evaluate their impact on vehicle performance, cost, and life.</td>
</tr>
<tr>
<td>P18.018</td>
<td>Advanced Vehicle Technologies for PEVs</td>
<td>This project will demonstrate the state-of-the art in bidirectional-communications capable, grid-integrated smart PEVs that enable dynamic load management, price signaling, and demand response applications.</td>
</tr>
</tbody>
</table>

**P18.001 Plug-in Hybrid Electric Vehicle Evaluation and Test Data Analysis (062128)**

**Key Research Question**

The first plug-in hybrid and battery electric passenger vehicles—collectively termed PEVs—from large automotive manufacturers entered the U.S. market in late 2010. There are a growing number of active PEV prototype and production vehicle test and demonstration programs in utility and public fleets. These programs are important opportunities to collect and analyze real-world operating data. This activity will enable utilities to understand the performance and operation of different types of PEVs, to understand customer usage and expectations, and to determine benefits and impacts to their systems.

**Approach**

This project provides a comprehensive real-world test program for the Electric Power Research Institute (EPRI) and utility PEV demonstration fleets. EPRI has developed a sophisticated system for collecting and processing detailed vehicle systems information and reporting the results to members. This information is valuable for utilities to understand how real-world PEV use impacts their system and business, to guide fleet “greening” and other environmental compliance issues, and to determine the most promising PHEV technological approaches. The scope of data collection and analysis includes:

- development of test procedures for field testing of prototype PEV fleets;
- acquisition and analysis of vehicle and system data from demonstration fleets;
- reporting and dissemination of vehicle test data;
- comparison to laboratory battery and component tests and verification of vehicle simulation data; and
- surveying transportation applications to determine potential PEV candidates and performing performance profile analyses on these candidates.
Impact
This project may have the following impacts:
- Increased understanding of PEV product performance
- Reduced fleet operating costs
- Facilitation of fleet environmental compliance
- Real-world data to support PEV benefit and impact analysis at the utility

How to Apply Results
Utilities can incorporate PEV test results into their internal analyses. Fleet managers can use the test data and vehicle specifications to acquire PEV technology for utility fleet operations. In addition, this project will enable EPRI and its advisors to carefully review the transportation sector and to identify transportation operating profiles and specific vehicle platforms as candidates for PHEV operation.

2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Plug-In Electric Vehicle Evaluation and Test Data Analysis: Results from plug-in electric vehicle (PEV) evaluations, and test data analysis.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

P18.003 Advanced Battery and Powertrain System Development for Plug-In Vehicles (063272)

Key Research Question
The potential for plug-in electric vehicles (PEVs) to achieve widespread market acceptance depends heavily on the cost, performance, and durability of the electric-drive systems and particularly the advanced lithium-ion (Li-ion) battery technology. Early testing by the Electric Power Research Institute (EPRI) and utilities of Li-ion battery systems against plug-in hybrid electric vehicle (PHEV) duty cycles provided some of the earliest evidence of the capability of the technology to meet PEV requirements. EPRI also has conducted extensive development, demonstration, and evaluation of electric-drive powertrain systems and components. New PEV design requirements and emerging technologies will continue to require additional systems development, technology evaluation, and testing.

Approach
EPRI will continue its industry-leading battery and electric-drive powertrain technology development and evaluation program. This project will identify and address issues of importance to the development and verification of PEV technology, including the following:

- Identification of technical issues related to PEV powertrain and battery systems, including cost, environmental impact, recycling, or manufacturing technology
- Evaluation of technical needs and gaps for future PEV powertrain technologies, including electric traction systems, on-board chargers, DC-DC converters, and electric accessories
- Development of suitable test procedures and methods for evaluation of advanced batteries for PEV applications
- Development of test plans and protocols for long-term life-cycle testing of candidate battery technologies
- Identification of synergies between automotive and stationary battery systems

Impact
This project may have the following impacts:
- Evaluate emerging PEV powertrain system and component technologies, including batteries
- Understand drivers for PEV battery system cost and environmental impact
• Obtain early identification and testing of promising emerging battery technologies
• Identify and address issues that affect PEV battery commercialization

How to Apply Results
The results from this project will provide member utilities with world-class, specific technical and cost information regarding battery and powertrain systems technology for PEVs. Member utilities will gain a thorough understanding of the readiness of Li-ion battery technology for PEVs—the single most substantial technical challenge to the development and commercialization of these vehicles.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Advanced Components for Plug-in Electric Vehicles</strong>: This deliverable will be an update describing the state of the art on batteries, motors, power electronics and other vehicle components technologies as of the end of 2012, in terms of performance, life, efficiency, and cost. Notable industry happenings from 2012 will also be included.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
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</table>

**P18.018 Advanced Vehicle Technologies for PEVs (071989)**

Key Research Question
As plug-in electric vehicles (PEVs) enter the marketplace in conjunction with smart grid technologies, there are a disparate and diverse set of technologies emerging on both the vehicle and smart grid side. PEVs constitute a significant new household load—sometimes doubling the household consumption, that is likely non-seasonal (people drive every day and will recharge their PEVs every night). Therefore, its integration into the distribution infrastructure will need to be managed through closed-loop control facilitated by bidirectional communications. There is a need for the intelligence on self-managing the vehicle’s grid-connected behavior to reside on the vehicle itself. In addition, this intelligence needs to be a part of the bigger, utility/automotive energy system that is coordinated at the utility end, requiring communications. There are currently a number of approaches to achieve this, many of which are proprietary or closed systems.

Approach
EPRI will utilize its ongoing collaborative efforts between utility and automotive industries to help develop technologies and demonstrate them as products as well as integrated systems. These efforts will enable PEVs to communicate with smart grid elements whether they are smart meters, advanced distribution automation systems, meter data management systems, or utility back-ends as follows:

• Identify open standards-based technologies to implement
• Design and develop technologies that can be deployed on-board any PEV
• Implement standards-based requirements into intelligent vehicle connectivity solutions
• Demonstrate cost-effectiveness, robustness, reliability, and security of intelligent vehicle connectivity

Impact
• Verify maturity and readiness of standards applicability to grid-connected vehicles
• Demonstrate viable set of technologies and suppliers that enable automotive-grade connectivity solutions
• Demonstrate cost-effectiveness, scalability, robustness, reliability, and security of smart PEVs to Smart Grid integrated systems with and without intermediaries
How to Apply Results

Member utilities will get access to case studies in developing their own roadmaps for getting the grid ready for intelligent grid-connected vehicles through hands-on demonstrations of these technologies on select PEVs. Member utilities also will get access to all of the demonstration related insights and data to help inform their own decisions on infrastructure investments and rate cases if applicable.

2012 Products

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Best Practices for Technology Architecture and Solutions for Smart Grid to Plug-in Electric Vehicles: Technical update with status of technology implementation efforts along with testing and evaluation results, if any.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

PS18B Non-Road and Fleet Applications (056054)

Project Set Description

This project set focuses on the application of electric-drive systems in non-road industrial, commercial, and airport and seaport markets whose technology successes will advance the awareness of the value of electric-drive systems.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P18.015</td>
<td>Non-Road Electric Vehicle Technology Assessment</td>
<td>This project will assess the performance, energy consumption, and emissions benefits of non-road electric vehicles.</td>
</tr>
<tr>
<td>P18.016</td>
<td>Fleet Applications for Plug-In Hybrid and Electric Vehicles</td>
<td>This project provides utility and customer fleet managers with guidelines and calculation tools to assist in planning fleet electrification.</td>
</tr>
<tr>
<td>P18.019</td>
<td>Non-Road and Fleet Vehicle Demonstration and Evaluation</td>
<td>This project investigates the application of electric-drive systems in non-road industrial, commercial, and airport and seaport markets.</td>
</tr>
</tbody>
</table>

P18.015 Non-Road Electric Vehicle Technology Assessment (070588)

Key Research Question

The adoption of non-road electric vehicles depends upon accurately understanding their benefits—real-world performance, lifecycle costs, and emissions reductions. Expanding non-road electric-drive technology into new applications requires a detailed technical understanding of the performance requirements of the vehicles in those applications.

Approach

This project will use a combination of test data from Project 18.006, other available test data, and existing literature to conduct technology assessments of non-road electric vehicles. This work will quantify the following aspects of non-road electric vehicle operation relative to combustion-powered equipment:

- Charging requirements and electricity consumption
- Fossil fuel consumption reductions
- Greenhouse gas and criteria emissions reductions
• Life-cycle operating costs
• Vehicle performance and capabilities

Impact
This project may have these impacts:
• Understand life-cycle performance, energy consumption, and emissions of non-road equipment
• Improve adoption of non-road electric vehicles by utility customers
• Inform environmental managers, policymakers, and other stakeholders of the emissions benefits of non-road EVs

How to Apply Results
Utility managers and account executives will use technical reports and other project data to inform customers and design non-road adoption or market expansion programs.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td>Performance requirements of Non-road electric vehicles: Understand life-cycle performance, energy consumption, and emissions of non-road equipment</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

P18.016 Fleet Applications for Plug-In Hybrid and Electric Vehicles (070589)

Key Research Question
In addition to currently available non-road electric vehicles, commercial fleets will face an increasing range of choices for electric and plug-in hybrid electric light-, medium-, and heavy-duty vehicles for their on-road fleet. Most fleet managers lack unbiased, accurate information to help them plan the acquisition of PEVs and the supporting infrastructure. Commercial fleets may represent a significant share of total PEV adoption in a community or region—however, lack of information and the risk of making poor initial decisions is an obstacle to adoption.

Approach
This project will utilize results from Projects 18.006 and 18.015 to develop guidelines and analytical tools to enable fleet managers to understand the technical capabilities of PEVs, accurately predict the performance of PEVs in their fleet applications, determine lifecycle costs, and calculate emissions and energy consumption benefits. The project also will develop an infrastructure planning tool that will help fleets develop preliminary electrical designs and understand charging equipment installation costs.

Impact
This project may have these impacts:
• Increase adoption of PEVs by the utility fleet and by commercial fleets owned by utility customers
• Provide unbiased, accurate PEV technical and performance data
• Enable accurate planning and understanding of infrastructure installations
• Enable fleets to determine optimum compliance pathways to meet environmental requirements

How to Apply Results
Utility fleet managers will use project guidelines and calculators to plan fleet electrification. Utility account executives and electric transportation staff will use project results to help utility customers electrify their fleets and plan charging infrastructure.
2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Alternative fueled light duty fleet guidelines:</strong> Guidelines and analytical tools to enable fleet managers to understand the technical capabilities of PEVs, accurately predict the performance of PEVs in their fleet applications, determine lifecycle costs, and calculate emissions and energy consumption benefits.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
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</table>

**P18.019 Non-Road and Fleet Vehicle Demonstration and Evaluation (071990)**

**Key Research Question**

This research focuses on the application of electric-drive systems in non-road industrial, commercial, and airport and seaport markets whose technology successes will advance the awareness of the value of electric-drive systems.

Increased success of non-road electric vehicle (EV) market penetration has most often resulted from actual product demonstrations spanning a diverse industry base that includes airports, food processing plants, and automotive manufacturers. Continued efforts in this area will enable ongoing market expansion.

**Approach**

This project will continue to seek and execute non-road EV demonstration projects across the United States. The scope of work is as follows:

- Review past demonstrations to identify types, locations, and level of success
- Define criteria that resulted in successful demonstrations
- Identify potential future demonstration projects across the United States and develop a scope of work for these projects

**Impact**

This project may have these impacts:

- Increase penetration of EVs in the non-road market
- Expand the market for utility products while enhancing customer satisfaction
- Achieve greater carbon dioxide (CO₂) emissions reductions
- Demonstrate EV technology validation in increasingly diverse applications
- Provide valuable market information to a national audience

**How to Apply Results**

Utility account executives will use case studies and reports that document the value of EV applications to establish interest in electric transportation from customers in their service territories as part of a non-road EV campaign.

**2012 Products**

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<tr>
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<tbody>
<tr>
<td><strong>Non-road Electric Vehicle Case Study:</strong> Demonstration results of EV technology validation with the objective of increased efficiency and reduced emissions</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
PS18D Electric Transportation Systems, Infrastructure, and Utility Readiness (056057)

Project Set Description
This project set addresses issues surrounding electric vehicle (EV) infrastructure and impacts on the utility grid as electric-drive systems enter the marketplace. Special attention is paid to the potential of plug-in hybrid and fuel cell vehicles to provide power to homes, commercial sites, and potentially the grid itself.

<table>
<thead>
<tr>
<th>Project Number</th>
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<tbody>
<tr>
<td>P18.010</td>
<td>Infrastructure Working Council</td>
<td>This project will provide support to the Infrastructure Working Council (IWC) for the execution of infrastructure analysis that affects the commercialization of plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) in the automotive and truck industries.</td>
</tr>
<tr>
<td>P18.020</td>
<td>PEV Charging Infrastructure - Evaluation, Planning and Business Models</td>
<td>This project will evaluate electric vehicle supply equipment (EVSE) and infrastructure, as well as develop planning and business models for deployment of EVSE in utility services territories.</td>
</tr>
<tr>
<td>P18.021</td>
<td>Grid Integration of PEVs</td>
<td>Development of models and framework to provide utilities with integrated, detailed, and localized estimates of electric vehicle adoption and associated impacts in the electric system.</td>
</tr>
<tr>
<td>P18.022</td>
<td>Utility PEV Readiness</td>
<td>This project will develop best practices for internal planning and management practices for utility PEV readiness programs.</td>
</tr>
<tr>
<td>P18.023</td>
<td>PEV Adoption and Load Forecasting</td>
<td>With plug-in electric vehicles (PEVs) poised to grow in the mainstream automotive market, electricity providers are working to account for the new electrical load in their planning process. Seamless integration of PEVs into the grid is a key concern of the utilities. While technological barriers to the commercialization of PEVs continue to fall, the expected influence of PEVs on the electrical system has not been completely evaluated. Understanding the relationships between this new load type and the utility system will help the utilities augment their planning processes to manage any additional stresses to their systems.</td>
</tr>
<tr>
<td>P18.024</td>
<td>Environmental and Economic Assessment of Electric Transportation</td>
<td>This project develops research methods for estimating electric vehicle adoption rates, and flow that information into electric vehicle readiness planning.</td>
</tr>
</tbody>
</table>

P18.010 Infrastructure Working Council (065239)

Key Research Question
The Infrastructure Working Council (IWC) was established to provide a forum for utilities, automotive manufacturers, suppliers, and other stakeholders to address issues regarding electric infrastructure for plug-in hybrid and electric vehicles. The IWC focuses on interoperability, safety, and simplicity of grid infrastructure as electrically powered vehicles enter the marketplace. The Electric Power Research Institute (EPRI) is well positioned to represent its members through support of the IWC and its activities to foster continued adoption of electric transportation technologies.

Approach
The IWC will continue to serve the industry as the facilitator of infrastructure review, analysis, and standardization. Project 18.010 will provide support to IWC for the execution of infrastructure analysis that positively affects the commercialization of plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) in the automotive and truck industries. This project also will conduct a representative sample audit of
airports and seaports across the United States and prepare a report with recommendations on airport and seaport infrastructure issues that should be addressed by the IWC. The scope of work is as follows:

- Lead utility industry participation in Society of Automotive Engineers plug-in electric standards development
- Lead or participate in relevant U.S. and international standards (IEEE 1547, NEC 625, and others) development
- Continue to identify and execute infrastructure projects that address issues, concerns, and standards that impact PHEV and BEV commercialization

Impact

This project may have the following impacts:

- Standardization of vehicle and stationary charging connection, equipment, and infrastructure for the interoperability and the safety of vehicle recharging
- Confirm that new standards facilitate communication between vehicle and grid to support industry needs for off-peak charging and electricity billing and tracking
- Minimize connectivity costs from both the grid and vehicle perspectives

How to Apply Results

Results from the IWC analysis will enable clean vehicle technology management teams at funding utilities and their customers to implement connectivity between the grid and electric vehicle (EV) systems. The reports developed will be used by members to confirm that connections are achievable and cost-effective.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tbody>
<tr>
<td>IWC Annual Report: This Technical Update summarizes work of the EPRI Infrastructure Working Council. The report provides an excellent overview of the Electric Transportation space and documents issues, updates and highlights of presentations given through the year.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

P18.020 PEV Charging Infrastructure - Evaluation, Planning and Business Models (071991)

Key Research Question

For plug-in electric vehicles to proliferate there must be sufficient charging infrastructure to make consumers confident that PEVs are a viable alternative to liquid petroleum fueled vehicles. In addition, this infrastructure must provide reliable and consistent performance from the consumer’s perspective and do so in a cost effective manner. EPRI will collaborate with utilities and infrastructure providers to assess the state of electric vehicle supply equipment (EVSE) technology from the hardware to deployment and operation.

Approach

The project will take a holistic approach to evaluation of electric vehicle supply equipment and infrastructure.

- Perform laboratory evaluation of hardware including compatibility, power quality and reliability evaluation.
- Lead utility industry efforts to develop infrastructure standards where such standards will enhance PEV acceptance and deployment.
- Develop deployment planning tools for utilities and other stakeholders.
- Model and quantify the economics of widespread plug-in vehicle charging infrastructure. Several potential business models will be considered and analyzed as part of the project.
Impact
- Provide funders with a clear understanding of available EVSE hardware
- Support utility learning for deployment of plug-in electric vehicle infrastructure
- Helps utilities understand the economics of widespread deployment of plug-in vehicle infrastructure

How to Apply Results
Member utilities will be able to use study results in infrastructure planning, field installation and in building both economic models of charging and in shaping the regulatory climate needed to facilitate PEV infrastructure.

2012 Products

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Evaluation, Planning and Business Models for Plug-In Electric Vehicle Infrastructure: This report summarizes the current state of electric vehicle supply equipment and related infrastructure elements, providing planning and business models for deployment of vehicle charging infrastructure.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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P18.021 Grid Integration of PEVs (071992)

Key Research Question
As technologies and demands continue to evolve on electric distribution networks, the ability of distribution utilities to continue to provide safe and reliable service requires operating and planning practices capable of accounting for these system changes. One of the changes that may dramatically influence distribution system design and operation include integration of plug-in electric vehicles to the grid. Incorporation of electric vehicles has led to a variety of questions related to grid impacts (loading and Power Quality), optimization, smart charging strategies, ancillary services capabilities. From a distribution planning perspective, the spatial and temporal variations associated with PEV charging make it difficult to predict using existing methods and tools. Further, the risk is exacerbated by the fact that the key source of the uncertainty and risk lies at a very local level (e.g. at the service transformer levels, small sections of the circuit).

Seamless integration of plug-in electric vehicles (PEVs) to the grid is a critical step to encourage utility support for PEV commercialization. Understanding the causes and relationships between this new load type and the distribution system will provide the ability for utilities to augment the planning process to account for any additional stresses to their systems. Assessing the extent of the impacts from of PEV adoption requires the development of detailed load models of Plug-in Electric Vehicles (PEVs), detailed models of existing distribution feeders of many different configurations and operating philosophies and subsequently advancing the state-of-art for distribution system planning, operations, and modeling.

Approach
This project builds on multi-year research conducted by EPRI to develop research methods and frameworks for understanding the distribution impacts of PEVs across 20 utilities. EPRI’s PEV Distribution Assessment initiative was a multi-year collaborative project to understand PEV grid impacts with several utilities in the United States and Europe. The initiative was launched mid 2008 with over 20 funders including one international funder. This project lays the platform for model-based management of the smart distribution system to integrate Plug-in Electric Vehicles (PEV) within the planning and operation of the system.

Methods, tools, and frameworks will be developed to understand the operational impacts of PEVs to the distribution system. New planning tools will be developed that will help manage the adoption of PEV within the power grid.
**Understanding the Operational Impacts to the Distribution system**

- Improved understanding of how PEV charging (AC as well as DC) will impact the grid
- Understand how the PEV growth and charging patterns influence the electrical network,
- Develop a consistent methodology to assess the "likely hourly impact" of adding PEV fleets on utility’s distribution system
- Understand the characteristics and features of the Fast Charger systems available commercially and under demonstration
- Evaluate impact of on-board and fast DC charging systems on PEV range extension and on utility infrastructure
- Assess interactions between the grid, PEVs, renewable resources, energy storage systems well as qualify the benefits through demonstration and detailed modeling.
- Improved understanding on the impact of distribution system power quality on battery charger operation (on-board as well as off-board chargers)
- Assess PEV charging effects on specific circuits within a utility’s distribution system and ensure distribution reliability in the face of increasing deployment of PEV and smart charging applications to the grid.

**Tools to help manage the system**

- Desired improvements in planning and modeling tools to design distribution systems that support and accelerate deployment of efficient end-use technologies such as plug-in hybrid electric vehicles.
- Development of asset management and screening tools and techniques which are capable of performing system wide evaluations of individual asset capacity against projected Plug-in Electric Vehicle (PEV) per-capita demands
- Development of tools capable of projecting and quantifying potential impacts due to PEV adoption across entire service territories and determine optimal distribution investment plans
- Proactive methodologies to identify which assets, or circuit sections, are likely to be at risk sooner than others, to forecast how EV load additions cluster into "hotspots" of localized risk, and to determine whether or not this additional clustered risk is consequential to the circuit, given the existing asset configurations

**Impact**

With this information, utilities may be able to:

- Understand how PEV growth and charging patterns influence the electrical network
- Accurately capture PEV load potential across the distribution system at a regional or census block level
- Provide for integration into asset management programs and/or system investment budgeting applications.

**How to Apply Results**

Employ the models and methods developed into:

- Utility distribution planning tools for near term implementation and assessment
- Utility electric vehicle readiness planning activities
- Utility asset management programs and/or system investment budgeting applications

**2012 Products**

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<th>Product Title &amp; Description</th>
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<tr>
<td>Grid Assessment Annual Report: Technical update on the development of models and framework to provide utilities with integrated, detailed, and localized estimates of electric vehicle adoption and associated impacts in the electric system.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>
P18.022 Utility PEV Readiness (071993)

Key Research Question

As electric utilities become the fuel provider for a growing fleet of plug-in electric vehicles, they must develop the internal planning and management processes to address this new paradigm. Not only will this impact load growth planning activities, it will open new avenues for utility/customer interaction. Utility development of internal programs to support PEV readiness will be a key factor to the growth in the use of plug-in electric vehicles.

Approach

EPRI will work with member utilities to develop best practices and guidelines for utility PEV readiness programs.

- Identify customer education opportunities and tools
- Help utilities identify internal bottlenecks in the infrastructure deployment process
- Study staffing and internal team structures used by utilities that have established successful PEV support deployment strategies
- Develop best practices for PEV readiness programs

Impact

- Position member utilities to proactively address issues and opportunities in the PEV arena
- Help utilities understand the internal structural changes that may need to be made to adequately address PEV readiness

How to Apply Results

Member utilities will be able to use the project results to develop internal PEV readiness tools, teaming strategies and support systems for successful deployment of PEV infrastructure.

2012 Products

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<tr>
<td>Plug-In Electric Vehicle Readiness Programs for Utilities: This report provides guidelines and best practices for development of plug-in electric vehicle readiness programs for utilities. The report focuses on practical methods and measures that utilities can use to prepare for widespread deployment of plug-in electric vehicles within their territory.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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P18.023 PEV Adoption and Load Forecasting (071994)

Key Research Question

The commercialization of plug-in hybrid and pure electric vehicles has created a need for utilities to prepare for the installation of charging infrastructure in their service territories and manage the impact of these new loads on the electric distribution system. As with any load, PEV demand exhibits its own unique set of diversity characteristics. Given the particular spatial and temporal uncertainties associated with charger locations and usage, traditional methods of load forecasting and distribution system analysis methods only provide limited understanding of the true impacts of PEVs on the system.

To characterize the effects, it is necessary to 1) Forecast the size of the PEV fleet and its electricity consumption 2) Evaluate a range of potential PEV adoption scenarios because the market for these vehicles is essentially new and the trajectory of sales is highly uncertain. The electricity use must be analyzed over long (for example, annual) and short (for example, hourly) timeframes in order to understand the system impacts. The expected size of the PEV fleet over time is a direct factor in the calculation of the different types of impacts on the electric utility system. The size of the total PEV fleet is based primarily on the addition of vehicles due to
annual new PEV sales. Using the fleet size and consumption forecasts, analysts can estimate the influence on grid operation, infrastructure, air quality and greenhouse gas emissions, and other areas of the electricity business.

Approach

This project builds on research conducted by EPRI to develop tools for PEV adoption forecasts (EPRI 1021635, 1019921, 1019727), distribution impact analysis, and consumer survey framework to gauge PEV awareness and perceptions (EPRI 1021285, EPRI 1022729, EPRI 1022728).

Additional refinements and approaches will be developed to better improve vehicle adoption estimates including the ability to tie to distribution planning tools.

- Incorporate results of surveys and the associated generalized adoption models implemented by EPRI and utilities to further refine Load Estimator algorithms and forecasts for utility service territories, regions, or rather specified geographic areas
- Additional refinements to include:
  - Permit evaluating impacts of time-varying utility rates on passenger vehicle charging scenarios
  - Extend the tool to include multiple vehicle types including commercial vehicle driving patterns and load forecasts
  - Expand NHTS analysis to differentiate
    - Residential/commercial/industrial locations
    - Charging scenarios
    - Vehicle types
- Develop methods, tools, and frameworks to integrate the load estimator within the EPRI Phase II Impact assessment screening tool
- Customized EV adoption forecasts across the service territory based on substation defined regions and GIS mapping framework
- Allow the user to customize known, or expected, PEV market characteristics or adoption centers at specific points in the system
- Permit multiple PEV market forecast scenarios (home only, work only, all locations)
- Enable user-defined inputs from customer market surveys, customers with fleets, customer segment demographics, parking garages, etc.

Impact

With this information, utilities may be able to:

- Understand how PEV growth and charging patterns influence the electrical network
- Accurately capture PEV load potential across the distribution system at a regional or census block level
- Generate forecasts of new plug-in vehicle sales in a specific geographical area and calculate relevant data including cumulative PEV market penetration, electricity demand of PEVs, and gasoline saved.
- Overlap the revised load estimator tool in the distribution screening tool for performing system wide evaluations of individual asset capacity against projected Plug-in Electric Vehicle (PEV) per-capita demands
- The load estimator and screening tool can be used to reassess the risks as system conditions and PEV projections change over time or across multiple scenario evaluations.
- PEV adoption tool will drive reevaluation of system design practices such as component sizing in future years
How to Apply Results

Employ the models and methods developed into:

- Utility distribution planning tools for near term implementation and assessment
- Utility electric vehicle readiness planning activities
- Utility asset management programs and/or system investment budgeting applications

In addition, utility planners can utilize a forecast of PEV fleet sizes to determine the most fundamental impact of PEVs, which include:

- Number of residential accounts that may potentially impact the utility system due to vehicle charging at home
- Extent of the need for public or commercial charging infrastructure
- Number of utility staff required to administer PEV-related programs and manage the various impacts of PEVs.

2012 Products

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<tr>
<td>PEV Load Estimation and Adoption: Technical update on development of models and framework to provide utilities with detailed forecasts of new plug-in vehicle sales.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P18.024 Environmental and Economic Assessment of Electric Transportation (071995)

Key Research Question

Electric vehicles are just now being made available by auto manufacturers. It will be 4-5 years before they achieve more than 5% of new car sales, but the number of cars on the road, and using charging stations at a variety of locations, may accelerate quickly thereafter. The slow initial build-up in vehicles on the road, which places increasing demands on electricity infrastructure, provides the electricity sector time to develop the organizational processes and functional organizations required to understand and forecast the implications of electric vehicles. That reprieve is important because of the time required for utilities to make infrastructure investments to extend facilities and make existing facilities capable of meeting new utilization demands. At the center of this transition process is credible and reliable forecasting tools to: 1) anticipate the rate of adoption of electric vehicles, 2) identify their home base (the residence where they are parked in the evening,) and other locations where charging services may be required or desired and when they will be used 3) predict the corresponding use of system implications, and 4) incorporate the results into utility and regional capacity and energy supply forecasting models.

Approach

This project builds on foundation research conducted by EPRI to develop research methods for implementing consumer surveys to gauge electric vehicle awareness and perceptions (EPRI 1021285, EPRI 1022729, EPRI 1022728), and to specify a framework for estimating electric vehicle adoption rates and incorporate that information into a electric vehicle readiness planning (EPRI 1019727).

Methods and protocols will be developed to use the results of surveys implemented by EPRI and utilities to develop forecasts of the rates of adoption of electric vehicles for utility service territories, regions, or rather specified geographic areas. An adoption model forecasts the rate at which electric vehicles are purchased and produces the corresponding estimate of the cumulative number of vehicles in the fleet. Typically, new technology adoption is characterized by replacement as starting slowly, gaining momentum, and then eventually
reaching a ceiling level. This time-indexed conversation to a new technology typically results in the iconic S adoption curve. EPRI will develop the adoption curve to produce estimates using localized or regional consumer survey data initially, and over time as electric vehicles become more prominent, incorporate electric vehicle sales data. The regional focus allows utilities to conduct consumer research when they determine it is appropriate and produce results that are directly applicable to their circumstances.

Vehicle adoption estimates will provide inputs to EPRI readiness processes and models that convert vehicle ownership (differentiated by survey data to characterize driving and charging behaviors) to produce estimates of: 1) time-differentiated requirements for energy for charging, and 2) feeder-level energy demands to support indentifying where local capacity reinforcements are most likely to be needed to support reliability.

Aggregate annual forecast of charging demands will be configured so that it be incorporated into utility capacity planning processes to direct capacity investments, and into operational and dispatch models to understand the consequences of electric vehicle charging demands. Adoption rates will be prepared using geospatial mapping to indicate clustering of the home based of electric vehicles and where they are likely to spend sufficient time to accommodate charging. This will inform distribution planning models so that utilities can anticipate and take action so that the added loads from charging can result in benefits to all stakeholders. Localized estimates of adoption can be shared with community organizations and businesses that seek promote and support electric vehicle adoption, for example local governments providing charging facilities and businesses considering doing the same.

Impact

Electric vehicle readiness initiatives will need adoption and impart forecasting tools to direct when and what infrastructure investments are most supportive of electric vehicle adoption and conducive to a positive ownership experience.

Utility planners will be able to explore the consequences of alternative adoption rates and consequential energy demand for charging on capacity requirements.

How to Apply Results

Employ the models and methods developed for utility or larger geographic areas electric vehicle readiness planning activities

2012 Products

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<tr>
<td>Methods and Protocols for Estimating the Localized Rate of Adoption Electric Vehicles and Associated Impacts: A Technical Report will describe how utilities, using EPRI models and methods, can estimate local electric vehicle adoption rates and the associated implications for supplying charging services.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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PS18E Advanced PEV Infrastructure and Smart Charging (071998)

Project Set Description

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<tr>
<td>P18.025</td>
<td>Smart Grid Technologies for PEV Grid Integration</td>
<td>This project will demonstrate the state-of-the-art in bidirectional-communications capable, grid-integrated smart PEVs that enable dynamic load management, price signaling, and demand response applications.</td>
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<tr>
<td>P18.026</td>
<td>Advanced Infrastructure Development and Testing</td>
<td>This project will provide the technical analysis and development work to support a single standard communication protocol and physical media for vehicle-to-grid communications.</td>
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P18.025 Smart Grid Technologies for PEV Grid Integration (071996)

Key Research Question

As plug-in electric vehicles (PEVs) enter the marketplace in conjunction with smart grid technologies, there are a disparate and diverse set of technologies emerging on both the vehicle and smart grid side. PEVs constitute a significant new household load—sometimes doubling the household consumption, that is likely non-seasonal (people drive every day and will recharge their PEVs every night). Therefore, its integration into the distribution infrastructure will need to be managed through closed-loop control facilitated by bidirectional communications. There is a need for the intelligence on self-managing the vehicle’s grid-connected behavior to reside on the vehicle itself. In addition, this intelligence needs to be a part of the bigger, utility/automotive energy system that is coordinated at the utility end, requiring communications. There are currently a number of approaches to achieve this, many of which are proprietary or closed systems.

Approach

EPRI will utilize its ongoing collaborative efforts between utility and automotive industries to help develop technologies and demonstrate them as products as well as integrated systems. These efforts will enable PEVs to communicate with smart grid elements whether they are smart meters, advanced distribution automation systems, meter data management systems, or utility back-ends as follows:

- Identify open standards-based technologies that could be implemented
- Implement standards-based requirements into intelligent vehicle connectivity solutions
- Demonstrate cost-effectiveness, robustness, reliability, and security of intelligent vehicle connectivity

Impact

- Verify maturity and readiness of standards applicability to grid-connected vehicles
- Demonstrate viable set of technologies and suppliers that enable automotive-grade connectivity solutions
- Demonstrate cost-effectiveness, scalability, robustness, reliability, and security of smart PEVs to Smart Grid integrated systems with and without intermediaries

How to Apply Results

Member utilities will get access to case studies in developing their own roadmaps for preparing the grid for intelligent grid-connected vehicles through hands-on demonstrations of these technologies on select PEVs. Member utilities also will have access to all of the demonstration related insights and data to help inform their own decisions on infrastructure investments and rate cases if applicable.
### 2012 Products

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<tr>
<td><strong>Best Practices for Technology Architecture and Solutions for Smart Grid to Plug-in Electric Vehicles:</strong> This technical update will summarize the latest smart grid interface technologies on-board the plug-in vehicles, prevailing approaches to communications, status of the applicable standards and applicable reference design approaches for on-vehicle standards-based solutions.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P18.026 Advanced Infrastructure Development and Testing (071997)

**Key Research Question**

Communication between plug-in hybrid electric vehicles (PHEVs) and grid infrastructure is the key element to maximizing the value of PHEVs as a connected load. As the market adopts PHEVs, utilities will need a means of communicating with these vehicles to incentivize off-peak charging, tracking, and billing the consumption of electricity as a transportation fuel and to optimize their use as distributed storage devices. There are a number of communication protocols and physical media—both wired and wireless—and their integration in advanced metering and other Smart Grid applications must be understood.

**Approach**

This project will provide the technical analysis and development work to support a single communication protocol and physical media that can be adopted as a standard by the automotive industry for vehicle-to-grid communication. The technical results of this project will support ongoing standards efforts in Project 18.010 and physical demonstrations in Project 18.017.

**Impact**

- Understanding of technical issues regarding vehicles communicating to grid infrastructure
- Development of a viable approach to create a single communication methodology applicable to plug-in hybrid vehicles from all automotive manufacturers
- Testing and validation of power line carrier (PLC), zigbee wireless, Smart Energy Profile (SEP 2.0), and other communication media and protocols applicable to electric vehicles
- Development of technical requirements and specifications for vehicle-to-grid communication

**How to Apply Results**

Results will be used in advanced planning for the integration of PHEVs into distribution systems. Member utilities will receive a technical specification document that can be used to clearly designate requirements to advanced metering infrastructure suppliers, regulators, and other stakeholders.
### 2012 Products

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<tr>
<td><strong>Vehicle and Infrastructure Connectivity and Communication Summary:</strong> This technical update will summarize the latest smart grid interface technologies that interface with the plug-in vehicle charging or Telematics systems. These include Smart Meters, Home Energy Management Systems, Distribution Automation Systems, Meter Data Management Systems and Enterprise IT systems. It will also describe prevailing approaches to communications, status of the applicable standards and applicable reference design approaches for standards-based solutions in each of the smart grid areas.</td>
<td>12/31/12</td>
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Supplemental Projects

Non-road Electric Transportation Market and Environmental Assessment Model and Demonstration (072000)

Background, Objectives, and New Learnings

Previous EPRI studies have revealed opportunities for reducing emissions and fuel consumption of non-road vehicles and stationary goods-moving equipment by converting them to electric drive. The studies have shown that electric drive non-road equipment can lessen the environmental impact of user operations and reduce end-user life cycle costs by cutting fuel costs, improving operating efficiencies, and lowering maintenance expense. The advantages of electric drive have been verified in various locations: at seaport loading docks, on airport runways, and in warehouses and manufacturing plants.

This project will apply the lessons from these studies and will synthesize existing case-based knowledge to create a model to quantify the environmental and economic impact to the energy provider of their end-use customers converting to electric drive. It will estimate the reduction in fossil fuel consumption and the resulting additional load and electric energy supply requirements. Transitioning non-road goods-moving equipment from using fossil fuel to electric energy may reduce environmental impact and carbon emissions enough to enable energy providers to comply with regulatory-mandated energy efficiency programs. Presently, however, an energy efficiency program’s effectiveness is evaluated only by considering total reduction of electric energy (kWh) use. The model will attempt to compare the reductions in environmental impact resulting from an electric-drive conversion program with a traditional energy efficiency improvement program, providing a basis for demonstrating that an electric-drive conversion program can provide comparable benefits.

The lessons about environmental and economic benefit that this project will provide can give energy providers the tools they need to create programs to motivate their customers to convert their non-road vehicles and goods-moving equipment to electric drive. At the national level, results of the project may be used by EPRI Electric Transportation to evaluate the emissions reduction potential of electrifying non-road vehicles.

Project Approach and Summary

This project will utilize results from work completed in 2010 that defined the operational and load characteristics of 36 non-road electric technologies. The technology assessment will be used to design a model to help energy providers to assess potential environmental and economic benefits of implementing a non-road electric transportation program.

Benefits

The anticipated benefits include:

- Identifying opportunities to reduce carbon emissions and environmental impacts
- Effectively apply investments to achieve lower energy costs for commercial and industrial customers
- Understanding the environmental impact of new technologies, and their potential for meeting environmental and efficiency policies and standards
- Quantify the economic impact to the energy provider of implementation of an non-road electric-drive conversion program
- Development of a regionally specific non-road electric transportation program
- Better operating efficiencies and lower maintenance expenses could lead to potential savings for consumers
Characterizing Consumer Preferences and Expectations for PEVs (072001)

Background, Objectives, and New Learnings

Plug-in Electric Vehicles (PEV), including Plug-in hybrid Electric Vehicles (PHEV) and Battery Electric Vehicles (BEV), are available in the market and new models continue to be developed. All major automakers are selling PEVs or have announced PEV models which will be available in the next 2-3 years. The PEV is advancing rapidly from a concept or hypothetical travel mode to a viable option for new car buyers.

The conversion of the fleet to PEVs can contribute substantially to reducing carbon dioxide and other harmful emissions associated with internal combustion engine-power vehicles, while providing consumers the reliable and cost-effective transportation services they expect. The adoption of PEVs may result in more efficient use of the electric system to the benefit of utilities and the customers that they serve. Finally, the switch to electric vehicles may serve as an important element to the revitalization of the U.S. automotive manufacturing sector, which would benefit all consumers. However, there are challenges to achieving these benefits.

The timing and amount of electricity used to charge PEVs will affect the electric system in many ways. Recharging opportunities may be extended beyond the household so that EV owners can charge at work, at public outlets (like parking garages and street parking meters), and at facilities built expressly for that purpose, but that offer much faster charging. However, the extent to which such infrastructure is essential or contributory depends on the relative adoption rate by vehicle type (PHEV or BEV), the cost of the various charging options, and many other factors that will be heavily influenced, if not largely determined, by consumers.

Preparing for this transformational technology requires building new infrastructure and developing commercial and institutional arrangements to support even a low level of PEV adoption. In order to identify the barriers and opportunities, and address them, a more comprehensive characterization of consumer preferences and needs relative to PEV adoption and utilization must be developed. Consumer preferences must be constructed by asking consumers about preferences for vehicles that are so new that most have never seen one, no less driven or ridden in one.

Project Approach and Summary

The objective will be accomplished by implementing a survey to solicit data from a representative sample of households in the utility market or other population of interest to characterize and portray:

- expectations and preferences regarding electric vehicle ownership and operation;
- where consumers expect to get information about PEVs;
- demographic attributes and driving behaviors; and
- willingness to pay for alternative levels of electric vehicle charging and PEV ownership

The survey response data will provide a detailed and localized characterization of the consumers that will support developing actions to meet immediate and local needs, including developing readiness plans for responding to customer wants and needs related to PEV ownership.

Benefits

The benefits of a more complete characterization of consumer needs and expectations will be widespread, including:

- The development of survey methods that can be employed throughout North America to reduce the costs and speed up the collection of essential data on consumer preferences and the readiness of households for PEVs.
- Implementing a consumer expectations survey will provide EPRI with the opportunity to further refine the survey instrument and add new data to more robustly characterize customer expectations to better address important considerations.
- Better characterizations of consumer behavior will promote and direct attention to a wide range of technical direct research efforts.
- The database on consumer preferences provides the basis for developing more credible portrayals of PEV adoption that are the foundation of several EPRI research tools.
- The findings will help utilities and other affected stakeholders forecast adoption rates for PEVs and to undertake PEV infrastructure and support system readiness activities that are aligned with what consumers want and expect.

The area-focused findings will support testing for differences among customers that are due to factors such as: driving behaviors; housing circumstances, electricity and gas prices; social influences; and access to information about PEVs.

These expected benefits will help utilities to meet the expectation of the public safely, and plan for additional infrastructure if necessary.

These expected benefits will help utilities to meet expectations of the public and plan for additional infrastructure if necessary.
PEV Distribution Impacts Analysis - Phase 2 GIS-Based Screening Tool (072002)

Background, Objectives, and New Learnings

The rapidly approaching commercialization of plug-in hybrid and electric vehicles has created an urgent need for utilities to support customer adoption of electric vehicles, prepare for the installation of charging infrastructure in their service territories, and manage the impact of these new loads on the electric distribution system. EPRI proposes the creation of a screening tool capable of performing system wide evaluations of individual asset capacity against projected Plug-in Electric Vehicle (PEV) demands.

In prior research, EPRI conducted a comprehensive study assessing PEV charging effects on specific circuits within a utility’s distribution system. This Phase I effort used very detailed simulations to develop summaries of general concerns, assets that are likely to be at most risk, conditions that could require additional monitoring to avoid problems, and the impacts of different charging profiles (including controlled charging) on these results.

The results of the research effort concluded that the short term impacts for most utilities should be minimal and localized. However, there is a need for the development of tools ongoing assessment of wider areas and identify locations and equipment most likely to be impacted than the general conclusions from the completed research.

This project is designed to establish proactive methodologies to identify which assets, or circuit sections, are likely to be at risk sooner than others, to forecast how EV load additions cluster into “hotspots” of localized risk, and to determine whether or not this additional clustered risk is consequential to the circuit, given the existing asset configurations.

Project Approach and Summary

The Phase II effort is focused on developing a screening tool capable of projecting and quantifying potential impacts due to PEV adoption across entire service territories. The screening tool will build on the results from Phase 1 but will incorporate the ability to integrate with databases of actual asset characteristics, customer load characteristics, distribution system loading characteristics, as well as projected penetration of electric vehicles as a function of customer characteristics. EPRI believes the screening tool’s ability to identify the risk assigned to each asset as well as identify geographic “hot spots” will provide for more effective asset management and reliability practices. Additionally, the screening tool can be used to reassess the risks as system conditions and PEV projections change over time or across multiple scenario evaluations.

Benefits

The screening tool will provide utilities with a more complete understanding of grid impacts associated with various PEV adoptions. Features include:

- Understand how the PEV growth and charging patterns influence the electrical network,
- Accurately capture PEV load potential across the distribution system at a regional or census block level. Accuracy of prediction at the service transformer level depends on the accuracy of market research forecasting, combined with the accuracy of the utility’s transformer ratings database and customer data from the billing system.
- Develop a consistent methodology to assess the “likely hourly impact” of adding PEV fleets on utility’s distribution system, and
- Ascertain levels of penetration and charging behaviors which result in excess demand requiring remediation or asset upgrades.

The developed framework considers the following principle factors that define PEV loading on distribution systems:
• Different PEV charging patterns (battery type, charger efficiency) and profiles
• PEV market penetration levels per utility customer class (residential, commercial)
• Time profiles and likely customer charging habits by season

The benefits to the public from this project are better utilization of the grid, increased opportunities for additional resources, and reduction of CO2 emissions in the production and delivery of electric power for the use in vehicles. These benefits are derived from a more effective planning process of PEV and improved practices for planning and operation of the public power supply.
Demonstration and Evaluation of Advanced PEV Infrastructure (072003)

Background, Objectives, and New Learnings

The Plug-In electric vehicle (PEV) market is growing and many emerging communications and control technologies are being utilized. As the number of PEVs in the market increases, there will be increasing interest in managing charging assets to minimize the impact on utility infrastructure. Creating charging methodologies and practices may help to minimize the cost of service to society through optimum use of existing grid assets. This project will assess new technologies through field demonstrations.

Funding members will be able to use the new knowledge from this project in planning and implementing advanced PEV infrastructure, gain firsthand experience with the technologies, and better understand the issues related to operating of new types of PEV support hardware. The funder will also gain insight in planning and implementation strategies for deploying advanced PEV support infrastructure.

Project Approach and Summary

EPRI will survey new and emerging technologies in the PEV infrastructure market. A limited number of the new technologies will be selected for field demonstration at participant sites. Technology areas to be surveyed will include novel electric vehicle supply equipment features, cable handling for charge stations, communications hardware, energy measurement devices, and charging control technologies.

The project will:
- Survey new, innovative technologies in the PEV infrastructure space
- Deploy a selection of these advanced technical solutions in field demonstrations
- Monitor the performance and quantify the benefits of the selected technologies

Benefits

This project offers a number of benefits to participants that could also serve the general public. These include:
- Identifying new, innovative technologies in the PEV infrastructure arena
- Providing hands on experience in field application and testing of the hardware.
- Identifying promising technologies that may allow utilities to deliver charging energy to vehicles while minimizing system impacts
End-Use Energy Efficiency and Demand Response - Program 170

Program Overview

Program Description
The electricity industry faces growing demand for power and the imperative to maintain reliable, affordable service while reducing carbon emissions. Utilities and policymakers in the United States and abroad are increasingly turning to energy efficiency as a resource to help address these challenges. Many U.S. states have enacted legislation that mandates specific energy efficiency savings goals, and some explicitly require utilities to place energy efficiency atop the loading order in resource planning. Key to the realization of these goals is the development and adoption of emerging energy-efficient technologies and best practices.

Research Value
The EPRI collaborative research program on End-Use Energy Efficiency and Demand Response is focused on the assessment, testing, and demonstration of energy-efficient and smart end-use devices to accelerate their adoption into utility programs, which can influence the progress of codes and standards and ultimately lead to market transformation. The program also develops analytical frameworks essential to utility application of energy efficiency, including assessment of resource potential, characterization of end-use load profiles, calculation of environmental impacts, and integration into utility resource planning.

This EPRI program provides the following:

- Objective, independent technical assessment, testing, and demonstration of emerging end-use technologies for energy efficiency and the enablement of demand response
- A framework to evaluate the readiness of emerging end-use technologies for utility programs, along a continuum spanning technology scouting, assessment and lab testing, R&D field testing and demonstration, coordinated early deployment, and full program rollout
- World-class laboratory facilities to test emerging end-use technologies in simulated environmental conditions, which mitigates members' technical risk for field demonstrations and larger scale deployments or programs
- Technical staff with expertise in heating, ventilating, and air conditioning (HVAC), lighting, water heating, motors, power electronics, data centers, industrial end uses, and controls
- Multilevel assessment of enabling technologies for demand response: components and devices, home and building premise application, and program integration into retail and wholesale markets
- Development of analytical frameworks to help utilities assess energy efficiency potential, characterize end-use load profiles, extract insights from smart meter data, calculate net carbon emissions impacts, and incorporate demand-side resources into resource planning

Approach

- Validate the performance of emerging end-use technologies—for example, energy savings, reliability, and compatibility—to develop deemed savings impacts to accelerate their adoption into programs and markets
- Develop Energy Efficiency Technology Assessment Guide, a compendium of technical, economic, and market readiness information for a comprehensive set of end-use technology categories, in 2012 and update it annually to serve as a convenient reference for utility professionals
- Produce in-depth, authoritative technical reports and guidebooks
- Provide knowledge transfer through concise technical briefs, fact sheets, newsletters, and topical webinars throughout the year to communicate insights to utility staff, including account representatives, and end-use customers
- Develop a model and database to help utilities conduct resource potential studies of energy efficiency potential, based on ongoing EPRI modeling to assess the technical, economic, and achievable potential for energy efficiency and peak demand reduction at the national and regional level
• Conduct large-scale multiyear field deployment of advanced energy-efficient technologies
• Develop and refine an industry-standard modeling approach to quantify the impact of energy efficiency on reducing carbon emissions to inform utilities, policymakers, and regulators

Accomplishments

• Risk mitigation and avoided costs
  • Assessment, testing, and demonstration of energy-efficient technologies to determine efficacy prior to deployments in utility pilots or programs
  • Assessment, testing, and demonstration of demand response–enabling technology to determine efficacy and interoperability prior to deployments in utility pilots or programs
  • Synthesis of end-use load research results and techniques to provide predictive insights into electricity use forecasts
• Input into standards development
  • Use-case functional specifications of demand response–ready end-use devices through a multidisciplinary process involving utilities, equipment manufacturers, public agencies, and other industry stakeholders
• Regulatory compliance
  • Establishment of national and regional benchmarks for energy efficiency and peak-demand reduction potential to inform discussions of state energy efficiency targets among members, policymakers, and other stakeholders
  • Analysis and recommendations for standardized measurement and verification (M&V) protocols for energy efficiency and demand response programs that can improve the cost effectiveness of program M&V and reduce the ambiguity of impact attribution

Current Year Activities

• Expand the scope and breadth of laboratory testing to keep pace with new technologies and members’ need to understand how the technologies work and characterize them in business cases
• Consolidate summary profiles of end-use technology categories into a comprehensive Energy Efficiency Technology Assessment Guide for convenient reference
• Develop methods for characterizing changes in household end use of electricity in a timely and cost-effective way
• Issue strategic technology briefs, industry briefs, workshops, and other practical knowledge transfer tools for members

Estimated 2012 Program Funding

$3.3M

Program Manager

Omar Siddiqui, 650-855-2328, osiddiqui@epri.com
Summary of Projects

PS170A Analytical Frameworks (65578)

Project Set Description

This project set develops and advances analytical frameworks, tools, and methodologies essential to utility application of energy efficiency, including assessment of resource potential, characterization of end-use load profiles, techniques to extract insights from smart meter data, calculation of carbon and other environmental emissions impacts, and integration into utility resource planning. This project set can help utilities assign value to the impact of energy efficiency and demand response technologies and programs. Participants will be well-positioned to quantify the full benefits of their energy efficiency and demand response portfolios and justify associated investments in regulatory filings.

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<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P170.002</td>
<td>Impact of Energy Efficiency on Emissions of CO2 and Other Pollutants</td>
<td>Refinement of EPRI National Electric System Simulation Integrated Evaluator (NESSIE) model as a potential industry-standard approach to converting energy efficiency savings to CO2, SOx, NOx, and Hg emissions reductions.</td>
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<tr>
<td>P170.005</td>
<td>Load Research: Translating Smart Meter Data into Customer Insights</td>
<td>Methods for fully using commercial smart meter data.</td>
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<td>P170.022</td>
<td>Energy Efficiency Potential Analysis Tools: Model and Database</td>
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<td>P170.023</td>
<td>Integrating Energy Efficiency and Demand Response into Resource Planning</td>
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P170.002 Impact of Energy Efficiency on Emissions of CO2 and Other Pollutants (069236)

Key Research Question

Little consensus exists among experts and policy makers on how to quantify the atmospheric emission reduction value of energy efficiency measures. A standardized and accepted methodology for this conversion would facilitate more accepted attribution of energy efficiency's impact on carbon emissions for policy considerations. Since 2007, EPRI has been examining the issue of assessing impact of energy efficiency measured on CO2 emissions, establishing in 2008 a proof-of-concept approach to calculating the marginal emissions reduction impact of selected major commercial end uses. In 2009, EPRI expanded its model to include major residential and industrial end uses and further refined this methodology to account for the impact of energy efficiency on capacity expansion. In 2010, EPRI developed a spreadsheet calculator based on its National Electric System Simulation Integrated Evaluator (NESSIE) model for members to perform customized analyses for their region. In 2011, this calculator was customized to facilitate the inclusion of utility-specific data inputs for CO2 emissions and end-use load profiles. The user interface and presentation of results were also enhanced to suit added functionality and ease of use. The 2011 calculator was also updated to reflect an expanded EPRI energy efficiency measure database.

Going forward in 2012 and beyond, EPRI intends to advance its methodology and results among utilities and policy makers as an analytically rigorous and practical approach to quantify as well as monetize energy
efficiency's impact not only on CO2 emissions, but also on other pollutants such as sulfur oxides (SOx), nitrogen oxides (NOx), and mercury (Hg). EPRI will also make annual updates to its NESSIE model and associated calculator tool to update emission reduction intensities based on the latest U.S. Annual Energy Outlook projections, data on regional generation resources, and end-use load shape characteristics.

Approach

This project entails the continued development and application of a modeling approach to help utilities and policymakers assess the impact of energy-efficient technologies on CO2 as well as SOx, NOx, and Hg emissions reductions. This project will use previous EPRI modeling work from 2008 to 2011 that applied EPRI's NESSIE load dispatch and capacity expansion model-to-model marginal CO2 emission reduction by end use. The product will be a technical update and set of data tables that ascribe marginal CO2, SOx, NOx, and Hg impacts for specific categories of energy efficiency as a function of U.S. region and market penetration, taking into account end-use load shapes and generation mix as a function of time.

Impact

This project provides utilities with an analytical basis to convert electricity savings from energy efficiency programs by end use into reductions in emissions that accomplish the following:

- Enable quantification of the emission reduction impact of energy-efficient technologies
- Offer members a framework to work effectively with customers, regulators, and policymakers to establish a societal business case for new technologies, enabling greater adoption of energy-efficient technologies
- Provide a bounded set of values for marginal CO2, SOx, NOx, and Hg impact that balances the need for analytical rigor consistent with prevailing emissions offset and trading markets with the practicality of utility implementation
- Enable monetization of emission costs

How to Apply Results

The data tables from this project will provide impacts on marginal emission of CO2, SOx, NOx, and Hg from a variety of major end uses as a function of U.S. North American Electric Reliability Council (NERC) region and assumptions of the market penetration levels of end-use efficient technologies. In this way, energy efficiency projects can achieve greater acceptance as a strategy for reduction of emission of these particular pollutants.

2012 Products

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tr>
<td>Calculator for Translating Energy Efficiency Savings into Emissions Reductions: 2012 Update</td>
<td>12/31/12</td>
<td>Assembled Package</td>
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</table>

P170.005 Load Research: Translating Smart Meter Data into Customer Insights (067472)

Key Research Question

There is growing evidence that consumers are changing the ways they use electricity. However, utilities are still relying on load profile data collected several years ago, in addition to even older and sparser end-use data, to understand customer behavior. As a result, there is a growing and troublesome disparity between how utilities plan to serve electricity loads, which involves large—and in many cases indivisible—investments in generation, transmission, and distribution plants and the loads they will actually serve. Just as important, utilities need to be able to characterize loads and their constituent elements to a higher level of detail to design pricing plans. Then utilities need to offer incentives to modify the level and profile of usage to better match underlying supply costs and reflect external costs. Moreover, realizing the benefits that appear to be associated with offering consumers timely and actionable feedback on usage requires establishing a robust characterization of all customer load profiles.
The universal deployment of smart meters provides the utility with the means to more accurately profile household load profiles and to track changes in those profiles over time. New load research methods are needed to be able to mine these data to provide insight and structure for pricing and feedback initiatives. Additionally, robust load research methods that can support other uses of smart meter data, such as supporting distribution system operations and enabling the adoption of distributed generation technologies, are needed.

**Approach**

In 2012, this project will focus on methods of extracting customer insights from usage information obtained from smart meters deployed in commercial buildings. The project will describe statistical and analytical methods that load researchers can employ to summarize the large body of data that smart metering generates from commercial buildings, generate routine reports, and conduct tailored research charters. The project will identify the data that can be gathered from smart meters at various types of commercial buildings to support pricing, feedback, forecasting, operations, and other applications that would realize value from more comprehensive characterization of load profiles.

The project builds on work conducted in 2011, which focused on extracting customer insights from household smart meter data.

**Impact**

- Develop immediate and beneficial uses for smart meter data
- Establish future metering spatial, temporal, and granulator metering requirements to guide the selection and deployment of metering technologies
- Provide the basis for customer segmentation to support the design of effective and efficient pricing plans, guiding the development of in-home displays and other feedback mechanisms, implementing energy efficiency programs, and fostering the adoption of efficient electric devices

**How to Apply Results**

Improved data on commercial electricity consumption will be valuable to every aspect of utility enterprise business activities, from system planning to pricing planning and energy efficiency program design to system operations and financial and accounting activities. Moreover, the results will be valuable for public policy inquiries aimed at improving sector performance and optimally achieving economic and environmental policy objectives.

**P170.022 Energy Efficiency Potential Analysis Tools: Model and Database (072089)**

**Key Research Question**

With the promulgation of energy efficiency savings mandates in many states and other jurisdictions, utilities and policy makers have a keen interest in understanding the potential for energy efficiency at the national, regional, subregional, state, and service-territory levels. Many load serving entities are required by their regulatory commissions to submit energy efficiency potential filings on a periodic basis; these undertakings typically require significant investment in consultants. Yet, the fundamental approach to modeling energy efficiency potential through equipment stock turnover is well understood and has been applied by many firms as well as EPRI. Moreover, utilities who engage firms to assist them in conducting studies of energy efficiency potential typically pay for existing databases of technology performance and costs. However, there is minimal sharing of such models or databases among utilities, which would make such studies consistent and comparable in addition to driving down their costs and timelines.

In response to this situation, this project will share EPRI tools that utility members can use to help them conduct energy efficiency potential studies more quickly, cost effectively, and in an industry-standard manner.
Approach

In this project, EPRI will share tools that utility members can use to help them conduct energy efficiency potential studies more quickly, cost effectively, and in an industry-standard manner. These tools include an equipment stock turnover model, a database of energy efficiency measures, and associated documentation in a technical report.

EPRI is continuously enhancing its energy efficiency potential model and database through ongoing assessments conducted at the national, regional, subregional, state, and service-territory levels. The current energy efficiency potential evaluation model represents largely static technology choices and costs and considers only electrical energy consumption. It is desirable to accommodate dynamic inputs throughout the forecast period to better represent the reality of customer decisions and technology evolution. For instance, a more efficient technology choice in 2012 might become the de facto standard in the future and therefore should represent the baseline consumer purchase where appropriate. To better represent the way in which stock of appliances changes over time, non-electric fuels must also be included in the process. This is particularly true in the case of space heating technologies where natural gas represents the majority of energy consumed for heating in the United States. The decision to replace a furnace with a more efficient heat pump provides a more complete picture of the impacts of highly efficient electrical technologies.

In this project, EPRI will update its base energy efficiency potential model to represent current technology choices and costs, which entails first updating the technology database by sector across the nine U.S. census divisions. In addition, fossil fuel consumption will be incorporated to model the impacts of fuel switching.

With updated energy and demand impacts and incremental technology costs, the mechanics of the model can be updated to incorporate changes over the forecast period. This will include factors such as the following:

- Changing technology costs
- Accelerated stock turnover
- Changes in codes and standards

With dynamic inputs, the model will better model changes in electricity consumption over time and allow sensitivity analyses to be performed, for example, to identify the impacts of varying levels of stock turnover rate.

Impact

This project will share EPRI tools that utility members can use to help them conduct energy efficiency potential studies more quickly, cost effectively, and in an industry-standard manner. These tools will include the following:

- An enhanced energy efficiency potential model that features fuel switching and allowance for dynamics over the forecast horizon to better represent the impacts of energy efficiency measures on fossil fuel consumption by U.S. census division
- An updated database of energy-efficient measures
- A technical report documenting the methodology behind the model and how to apply it

How to Apply Results

The tools produced in this project—report, software model, and database—can be applied by utilities to conduct customized studies of energy efficiency potential more quickly, conveniently, and at lower cost. EPRI can assist interested utilities in applying the results in supplemental studies.
P170.023 Integrating Energy Efficiency and Demand Response into Resource Planning (072090)

Key Research Question

A key aspect of effective demand-side planning—including energy efficiency and demand response—is the inclusion of projected impacts into the utility resource planning process. The inherent nature of demand-side resources, including their varying product life cycles and dependence on consumer behavior, make it more complicated to incorporate into the resource planning process. Resource planning uses fixed blocks of generating capacity and fuel costs with assumed lifetimes. This makes dynamic modeling of alternative supply-side and purchase options a more reasonable possibility. Energy efficiency is different in that its impacts build over time, producing cost savings that might be difficult to isolate and have operational and risk characteristics that make them more or less flexible than conventional supply-side resources.

Approach

This project will take a twofold approach. The first is a survey and summary of methods used by utilities to incorporate their planned energy efficiency and demand response activities into their resource planning process, with case studies. The second is the identification of factors that prevent their inclusion as a dynamic resource and an exploration of techniques to overcome those barriers.

Impact

More precise modeling of energy efficiency and demand response impacts and their inclusion in resource planning can yield significant cost savings to utilities. It would help utilities determine the optimal investment in energy efficiency and demand response resources to achieve cost-effective resource objectives.

How to Apply Results

A technical update will be produced that will allow utility demand-side program designers and resource planners to more realistically include the energy efficiency and demand response costs and impacts into their resource planning process.

PS170B Demand Response Systems (65571)

Project Set Description

The projects in this set assess, test, and demonstrate the application of technological advances in integrated energy management control systems, linking smart thermostats, lighting controls, and other load control technology with smart end-use devices to enable more sophisticated and effective demand response, such as dynamic energy management, in homes and buildings. The project set also examines technological advances in permanent load-shifting techniques such as thermal storage and its integration into demand response systems for load shaping and peak load management. This project set addresses the decision criteria for developing a demand response portfolio in the context of retail and wholesale market structures. Finally, it offers members a unique opportunity to work collaboratively with other utilities, government agencies, and manufacturers to define the requirements of end-use devices that are designed "DR-ready," that is, able to participate in demand response programs "out of the box," which carries the potential for dramatic operational and cost benefits to members.
Project Number | Project Title | Description
--- | --- | ---
P170.006 | Enabling DR-Ready Devices and Programs | This project continues the activities started in 2009 to identify the functional capabilities for selected residential end-use devices so that they are considered demand response ready ("DR ready"), that is, ready to participate in DR programs “out of the box.” The 2012 project will focus on disseminating the functional capabilities developed by diverse stakeholders so that they can be applied in prototype devices. Two reports will be generated—one on the DR capabilities of actual product prototypes and another that is a guidebook for utilities on program elements that need to be in place in order for DR-ready devices to become viable consumer products.
P170.007 | Peak Load Management of Thermal Loads | This project assesses and demonstrates the state of the art in thermal energy storage (TES) technologies.
P170.009 | Intelligent Buildings | This is a third-party examination of integrated systems for building and lighting controls that make up intelligent buildings. The project consists of two parts. One part addresses state-of-the-art building controls for demand response, with a focus on the grocery and convenience store segment. It assesses the integration of demand response gateways into existing building energy management systems that feature interoperable and open communication standards. The second part determines realistic performance, market potential, energy impact, and improved quality of light that can be expected with the use of intelligent lighting control.
P170.018 | Demand Response Program Assessment Tools (Retail and Wholesale) | In 2011, this project developed an evaluation framework for demand response implementation options. In 2012, the project will expand to consider wholesale market opportunities and risks associated with demand response. Given existing opportunities and risks stemming from wholesale markets, the project will provide operational guidelines for integrating retail demand response programs in wholesale electricity markets.

P170.006 Enabling DR-Ready Devices and Programs (067473)

**Key Research Question**

Despite its well-documented and demonstrated benefits to society, utilities, and consumers, demand response (DR) remains a critically underused resource in the United States. One of the key barriers to greater participation is the cost to utilities of installing equipment in buildings and homes to enable load control and demand responsiveness, such as programmable communicating thermostats and sensors on air conditioners, appliances, water heaters, pool pumps, lighting, and other large end uses that contribute to peak demand. Experience also suggests that customers’ reluctance to have unknown controls installed in their homes or businesses is a barrier to more widespread participation in utility DR programs. However, these barriers would be overcome if major energy-consuming appliances and devices came ready to participate in DR programs out of the box ("DR-ready").

**Approach**

DR-ready is the capability of an end-use device to receive a signal from a utility, such as price information or an emergency message, and the capability of a device to respond automatically to that signal by modulating operation to reduce or shift demand. This project will expand on efforts of 2009–2011 to accomplish the following:

- Identify detailed functional capabilities of devices so they can be considered DR ready.
Identify functional capabilities in a way that describes what a system must be able to accomplish, given specific inputs and conditions (for example, shift load for a certain period of time or reduce load by a certain percentage). The intent is not to prescribe how these functions will be performed (although examples of functions are being provided as part of the documentation). These functional capabilities are being identified through a collaborative, iterative process in which a diverse group of stakeholders—including DOE, EPA, utilities, equipment manufacturers, policy makers, and regulators—engage in a process to reach consensus on essential functional capabilities.

Identify utility programs that are most likely to be supported by device manufacturers and consumers, including factors such as whether there is one- or two-way communication with the device and how consumer privacy is addressed.

Develop a roadmap for industry migration to ubiquitous mass-market demand response.

2012 research, development, and demonstration efforts will focus on the following:

**Functional capabilities of existing DR-ready prototype devices.** Two main activities will be pursued to inform all stakeholders of the functional capabilities identified through this project and help them to apply this information as appropriate, with the ultimate goal of showing the value of commercially available DR-ready products:

- Document the capabilities of prototypes of DR-ready devices developed by manufacturers. This will include the capabilities of device prototypes prepared as part of a related EPRI effort to create a DR modular interface for residential devices that receives signals from utilities. Data will be collected at sessions designed to test the modular socket interface using prototypes developed for that purpose by participating equipment manufacturers. Also documented will be the capabilities of "smart-grid ready" appliances that major manufacturers are developing and have displayed as future product concepts at venues such as the Consumer Electronics Show. Documentation will include the customer setting or programming choices for the DR-ready device and how they are defined.

- Inform and work with organizations that deal with voluntary specifications and standards for equipment ratings, labels, or qualifying criteria for utility and government rebates so that they are aware of and can use the DR-ready functional capabilities developed through this EPRI project.

These activities will take into account continuing developments in communications protocols and common information models that might provide standardized syntax for price signals and other utility-to-device communications.

**Guidebook for utility DR programs that use DR-ready appliances.** DR-ready products and utility programs must be developed in tandem. DR-ready devices need to be available to consumers, but to be of value to the consumer and marketable by retailers, utility programs also need to be in place so that consumers can fully benefit from buying the technology. Building on 2011 guidelines for demand response programs that could be acceptable for manufacturers and consumers, this project will delineate how utilities can become ready for DR-ready devices. This will include identifying what works within the architecture of the smart grid, within varying rate structures, and within the capabilities of the devices and the choices provided to consumers.

The project builds on EPRI collaboration with EPA and DOE in 2008–2011 and with manufacturers and other stakeholders to identify opportunities to make an appliance’s DR-ready communications capability a labeled attribute for selected categories of end-use devices going forward.

**Impact**

- Have firsthand influence in shaping the utility industry's functional requirements for DR-ready end-use technologies to create alignment with members' current and future DR objectives.
• Work through utility collaborative to influence EPA and DOE ENERGY STAR labels to include DR-ready functionality.
• Work through a utility collaborative to influence equipment manufacturers to develop DR-ready equipment.
• Improve the cost effectiveness of future DR programs by avoiding the expense of installing on-site equipment for participating customers through DR-ready end-use devices.
• Increase DR capability and expand the potential market of DR program members through the market entry of DR-ready end-use devices.

How to Apply Results

Members will have firsthand access to influence the utility industry’s functional capabilities defining what constitutes a “DR-ready” end-use device. Utility staff involved in the planning and design of DR programs and advanced metering infrastructure (AMI)/smart grid systems can apply the project findings and deliverables to match DR program requirements to desired end-use equipment attributes that would allow for “out-of-the-box” program compatibility. Equipment manufacturers can apply the functionality guidelines established through this project to develop and refine prototype DR-ready technologies, which can, in turn, be tested in EPRI’s Living Laboratory and could be deployed in field trials in members’ service territories in conjunction with their DR programs. The eventual advent of DR-ready devices into the marketplace can expand members’ DR potential, increase dispatchability and reliability, and lower program operating costs.

P170.007 Peak Load Management of Thermal Loads (067474)

Key Research Question

Reduction of peak loads and shifting such loads to off-peak are important issues facing utilities. One established technology for shifting cooling and heating demand from on-peak to off-peak periods is thermal energy storage (TES). This technology offers a cost-effective way to respond to peak demand crises. It also is an option that can efficiently enhance the productivity of HVAC systems. Many experts agree that TES technology is poised to become a more important part of HVAC markets. However, TES remains an underused technology, in spite of the fact that cool storage is an appropriate technology in approximately 60–80% of new commercial installations. With the rising importance of demand response (DR) and peak load reduction, the adoption of TES technologies is expected to accelerate in the next few years. Important questions that remain are the impact of TES on DR responsiveness and on overall energy efficiency.

Approach

This technology is used to shift load from on-peak periods to off-peak periods. In cool storage, a vapor compression system cools a storage medium during off-peak hours. During peak periods, a heat transfer fluid or the storage medium itself is pumped through the delivery system, discharging the storage medium while avoiding compressor operation. Many different approaches have been taken to develop a cool storage system with the most attractive combination of cost, performance, and size, including water storage, ice storage, and eutectics. This project is a continuation of activities conducted between 2008 and 2011 and included testing of commercially available TES units.

Efforts in 2012 will include the incorporation of technical advances looking at both cold and hot storage methods, including storage of hot water to manage peak loads. Recently developed building materials with embedded phase-change material will be evaluated for use in shifting and dampening the daily peak loading of buildings. Assessments will be focused on the amount, placement, cost, and climate-specific effectiveness of these new building materials. Other new traditional thermal storage technologies are being developed from international sources, particularly Japan (such as TES with an Eco-Cute water heater and eutectic materials). TES technology will be examined to identify the features of available units, testing the most promising systems for the North American and other markets, publicizing the results, and acting on any improvement opportunities uncovered in the evaluation.
Impact

- Benefit from unbiased technical assessments of new TES technologies with the potential to reduce demand and shift substantial load to off-peak hours and understand their impact on energy efficiency
- Assess state-of-the-art international and U.S. TES technologies for DR applications
- Increase understanding of how TES technologies function in actual applications
- Establish capability to transfer new TES technologies to utility customers, building operators, and commercial customers
- Enhance customer confidence by demonstrating a member’s value as an energy management partner

How to Apply Results

Project findings and products will be employed by utility account representatives, marketing staff, and energy efficiency specialists as they work closely with customers in key residential, commercial, and industrial market segments and transfer new technology that can help utilities shift or lower peak demand. Members also can help customers improve energy efficiency, reduce pollution, enhance indoor air quality, and improve productivity.

2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tr>
<td>Peak Load Management of Thermal Loads Using Advanced TES Technologies: Analysis and testing of advanced TES technologies for peak load management, including advanced water storage and phase change materials technologies. Identify the features of available units, test the most promising systems for the US markets, and act on any improvement opportunities that are uncovered in the evaluation.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P170.009 Intelligent Buildings (067476)

Key Research Question

An intelligent building has the capacity to provide a safe, healthy, and comfortable environment for its occupants and to improve operational efficiencies for its owners. An intelligent building also responds to grid conditions to help utilities manage demand. Moreover, the level of intelligence can be determined by the capability of the building to optimize benefits to all three parties: occupants, owners, and the utility. There are two main systems within intelligent buildings: building control systems and lighting control systems.

Evaluating the performance of advanced building control and lighting control systems in enabling more automated and ubiquitous demand response with respect to the requirements of building owners, occupants, and the utility can foster their more widespread use to help meet future energy and demand objectives. Control systems used in intelligent buildings should support configurable control strategies in which building owners and/or occupants can program or select subroutines to optimize performance levels based on a variety of parameters, such as external price signals—including real-time pricing (RTP), time-of-use (TOU), reliability-driven demand response events, external ambient conditions, and occupant preferences.

Approach

This project consists of two subsets:

- **Building Control Systems**: This activity is a continuation of projects from 2007 through 2011 and builds on the technical studies of building automation and control systems for demand response applications. Results from earlier projects include case studies for four building types based on the technical and business viability of assisting commercial building owners with improving efficiency and providing an integrated solution with the building automation systems. It also includes an assessment of controls and...
demand response for large office buildings completed in 2011. The 2012 activity will continue the assessment of state-of-the-art building controls for demand response by focusing on grocery and convenience stores. It will include a technical review of the important refrigeration loads of grocery and convenience stores. Enabling technologies include demand response gateways for utility price and capacity signals as well as dashboards that communicate energy consumption, power draw, and other economic and environmental conditions to building managers.

- **Lighting Control Systems**: The identification of lighting control systems is carried out by conducting extensive product searches; attending lighting control fairs, conferences, and demand response expositions; and engaging with existing and new manufacturers of lighting controls. New technologies will be procured for testing and evaluation in EPRI’s Living Laboratory in Knoxville, Tennessee. Lighting control research engineers also will be engaged to understand the direction of standards efforts and the requirements to support emerging lighting control technologies.

**Impact**

Comprehensive evaluations of building and lighting control systems can be used by energy, lighting, and control engineers to aid in the decision process before control technologies are considered for energy efficiency and rebate or incentive programs. Additional value can be realized through the following:

- Providing opportunities for utilities to demonstrate leadership in environmental stewardship through deployment of vetted lighting control systems
- Understanding the impact of allowing lighting control systems to manage lighting loads in facility power systems
- Providing opportunities for utilities to integrate pricing gateways into smart building management systems
- Gaining knowledge regarding the use of more intelligent yet easy-to-operate building management and lighting controls
- Understanding which technologies are more favorable for use with future demand response systems
- Helping ensure realistic performance that can be matched with product warranty expectations

**How to Apply Results**

Project findings and products will be employed by utility account representatives, marketing staff, and energy efficiency and demand response specialists as they work closely with their customers in key residential and commercial market segments to transfer new technologies and implement dynamic pricing models that can help customers by reducing peak demand and energy costs and directly address their comfort and business needs. Comparison of electrical, efficiency, and photometric performance among traditional noncontrolled light sources and lighting systems and those that are controlled in various commercial environments will allow members to determine expected energy reduction for system planning purposes. Project results will allow members to determine future energy and power quality requirements for supporting these technologies and the benefits of using lighting control systems combined with building control and demand response systems. Project data will provide a foundation for members to compare field data from future installations with project and demonstration data.

**2012 Products**

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<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Intelligent Building Series, Volume 2: Grocery and Convenience Stores:</strong></td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>Continuation of technical assessment of state-of-the-art building controls for demand response, with a focus on the grocery and convenience store segment. Examination and detailing of the integration of demand response gateways and dashboards into existing building energy management systems that feature interoperability and communications.</td>
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A parallel study on state-of-the-art energy-efficient buildings in Project Set 170C addresses the same building segment, grocery and convenience stores, in 2012.

**Lighting Control Systems**: Continuation of examination of emerging light dimming and control systems.
Continuation of the examination of lighting control systems identifying realistic performance, market potential, energy and demand impact, and improved quality of light associated with the use of intelligent lighting control. Additional research will include system compatibility testing and analysis to ensure systems can operate in the electrical environment they are envisioned for. EPRI’s interaction with lighting control manufacturers and technology developers provides effective identification of modern lighting control systems and components. Wireless, analog (0 to 10 volt), digital (e.g., DALI), power-line carrier, and systems using hybrid communication are candidates for this project.

**Future Year Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intelligent Building Series, Volume 3: Big Box Stores:</td>
<td>12/31/13</td>
<td>Technical Update</td>
</tr>
<tr>
<td>EPRI will continue the annual focus on the application of advanced building control systems for energy management and demand response for a given building segment. In 2011, the selected building segment was large office buildings, and in 2012 the segment is grocery and convenience stores. In future years, EPRI will address additional building segments, including hospitals, hotels, retail, and restaurants.</td>
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</table>

**P170.018 Demand Response Program Assessment Tools (Retail and Wholesale) (067473)**

**Key Research Question**

The electric power industry operates with retail load largely disconnected from wholesale grid and market conditions. Workable and sustainable demand response (DR) options are needed that enhance responsiveness of retail load to electric power grid and/or wholesale market conditions. Moreover, enhanced clarity is needed on DR options coupled with customer engagement models, enabling technologies, and other choices for installing and operating DR resources in a coordinated fashion with power system needs and constraints. The project will provide assessment tools designed to assist the utility in steering DR implementation choices in alignment with the drivers that determine the long-term sustainability of chosen options.

**Approach**

The project will develop and illustrate methods and tools that utilities could apply to help evaluate different DR implementation options available, amid several possibilities with advanced metering infrastructure, incentives models, premise/grid information exchange requirements, and so on. The project will produce a technical summary of options available. A range of distinct uses of DR will also be illustrated. Results are intended to be readily applicable by utilities for evaluating and comparing different DR implementation options. Dimensions to be considered include regulatory and policy drivers, commercial justification, technical enablers, operational capabilities, and risks.

Through webcasts and one-on-one phone interviews, EPRI will seek input from utilities to establish a level of detail to target and present draft findings for feedback. A technical summary will be generated, providing context and highlighting tools developed as well as examples of their practical application.
Impact

Project findings will enable utilities to consider implementation options with an eye toward long-term sustainability. Additional benefits include the following:

- Ability to assess a range of considerations impacting the long-term viability of DR implementations
- Clarity on wholesale market opportunities available for DR
- Understanding penalty risks and strategies for mitigating them when integrating retail DR in wholesale markets

How to Apply Results

Results can be applied to describe and identify where value (for example, improved or maintained reliability, and market economics) can be realized using DR through different implementation options. Results can also be used to describe how the smart grid, using specific information exchange and technical capabilities, enables different types of retail incentive and engagement models.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Guidelines for Integrating Retail Demand Response Programs in Wholesale Electricity Markets: Opportunities and risks are identified for demand response participation in wholesale electricity markets. An assessment of penalty structures is also provided for demand response in wholesale markets. Considering current wholesale market opportunities and penalty structures for demand response, this deliverable provides operational guidelines for integrating retail demand response programs in wholesale electricity markets.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

PS170C Energy Efficient Technologies (067430)

Project Set Description

This project set assesses, tests, and demonstrates the application of advanced energy-efficient technologies in major and rapidly expanding end uses across the residential, commercial, and industrial sectors. Participation in this project set provides firsthand performance data on novel efficient technologies and can facilitate field demonstrations in members’ own service territories and eventual programs to increase energy efficiency to meet regulatory energy efficiency goals. Activities will test the performance of, and examine opportunities to remove adoption barriers for, novel heat pump technologies for space conditioning and water heating, advanced lighting technologies, and “hyper-efficient” residential appliances and office equipment that together represent significant energy savings potential. The project set addresses the industrial sector through the extension of an energy management tool into new industrial market segments as well as the assessment of advanced motors and motor-drive technology. Finally, it addresses opportunities for energy efficiency in areas of energy growth, such as data centers and power supplies for consumer electronics.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P170.013</td>
<td>HVAC and Water Heating</td>
<td>Unbiased technical assessment and laboratory and field demonstrations of new energy-efficient space conditioning and water heating technologies with the potential to substantially increase HVAC efficiency.</td>
</tr>
<tr>
<td></td>
<td>Technologies</td>
<td></td>
</tr>
<tr>
<td>P170.019</td>
<td>Industrial Energy Efficiency</td>
<td>The industrial energy efficiency project will develop case studies and application documents in two specific areas of opportunity that include motors and drives and process heating.</td>
</tr>
</tbody>
</table>
### Project Number: P170.020
#### Project Title: High-Performance Homes and Buildings
This project will provide unbiased technical assessments of improving energy efficiency in data centers and zero-net energy grocery and convenience stores. Assessments will be done in collaboration with federal and state institutions, standards bodies, and other stakeholders. The ultimate goal of the assessments is to provide information that leads to improved productivity and comfort of occupants and customers and decreased energy intensity of buildings. Technical assessments will address whole building approaches and convergence of trends in efficient design and technologies along with how they integrate with the grid and utility practices.

### Project Number: P170.021
#### Project Title: Electronics, Plug Loads, and Lighting Efficiency

**Electronics and Plug Loads**
This research is part of an ongoing effort to engage vendors, utility programs, and standards bodies to push the efficiency limits of electronics products to higher levels, saving billions of kWh per year in the process. In 2011, efforts will include baseline measurements and specification development for uninterruptible power supplies, network devices, and smart meter power supplies.

**Advanced Lighting Technologies**
This research is a third-party examination of new advanced lighting technologies that identify realistic performance, market potential, energy impact, ruggedness, and improved quality of light.

### Project Number: P170.013
#### Project Title: HVAC and Water Heating Technologies (067479)

**Key Research Question**
Heating, ventilation, air conditioning, and water heating with high coefficient of performance are efficient technologies that can significantly reduce energy use by residential and commercial customers, also reducing costs and greenhouse gas emissions such as carbon dioxide. Breakthrough adoption of advanced air-source heat pumps, combined cooling and dehumidifying technologies and heat pump water heaters hinges on functional and cost improvements. Improved performance at very high and low outdoor temperatures is a priority for many applications, especially in hot/dry, hot/humid, and sub-zero conditions. Such advanced systems also have the ability for improving customers' comfort.

**Approach**
The project will consist of two subsets:

- **Variable-Speed Air-Source Heat Pumps**: Variable-speed air-source heat pump technology continues to advance with new products being developed by U.S. and foreign manufacturers. The 2012 effort will continue to assess the latest advances in vapor compression heat pump technology, including systems developed specifically for the American market such as commercial packaged unitary and residential ducted multi-split systems. Emphasis will be on matching system types and performance to climate-specific needs, which vary significantly across the country. The codes and standards review for small unitary equipment developed in 2011 will be expanded to include large unitary equipment.

- **Heat Pump Water Heaters**: Heat pumps have been used in niche markets for commercial water heating. New developments in technology for both conventional refrigerant systems, such as R-410a and more advanced systems using carbon dioxide, are being made. Carbon dioxide is an effective refrigerant for water heating because it maintains high coefficient of performance with high temperature gradients, allowing water to be heated to temperatures in excess of 200°F. Coefficients of performance can range...
from 2.5 for 410a systems to 4.0+ for CO2 based systems. Combined space conditioning and water heating heat pump technologies are also being developed and introduced to the market. This project will test the performance of several newly available products aimed at small- to medium-sized residential and/or commercial applications.

**Impact**

The project delivers unbiased technical assessment and laboratory and field demonstrations of new energy-efficient space conditioning and water heating technologies with the potential to substantially increase efficiency. The project seeks to achieve the following:

- Increase understanding of how the technologies function in actual applications
- Establish the capability to widely transfer the technology to vendors, developers, and customers
- Help reduce greenhouse gas emissions and contribute to the deferment of power plant additions through energy-efficient space conditioning
- Improve economic development by reducing customer facility energy costs

**How to Apply Results**

Project findings and products will be employed by utility account representatives, marketing staff, and energy efficiency specialists as they work closely with their customers in key residential, commercial, and industrial market segments. These members will transfer new technology that can help customers reduce costs and improve energy efficiency, reduce pollution, enhance indoor air quality, lower peak demand, and improve comfort and productivity.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced Air Source Heat Pump Technologies:</strong> Assess and test the latest advances in vapor compression heat pump technology for the US market such as commercial packaged unitary and residential ducted multi-split systems. Match system types and performance to climate specific needs. Review codes &amp; standards for small and large unitary equipment.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Advanced Heat Pump Water Heating Technologies:</strong> Assess and test the performance of several newly available products aimed at small- to medium-sized residential and/or commercial applications.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

**P170.019 Industrial Energy Efficiency (069238)**

**Key Research Question**

As global competition intensifies, industrial customers are looking for ways to cut energy costs, improve efficiency, improve productivity and yield, and address increasingly stringent environmental regulations. By providing the knowledge, tools, and support that industrial customers need to optimize their energy expenditures, utilities can create "win-win" opportunities—enhancing customer energy efficiency, reducing the carbon footprint, retaining market share, and creating business opportunities.

Advanced, efficient electrotechnologies for industrial applications create unique opportunities for utilities to help improve overall energy efficiency of customer processes, increase energy intensity, reduce the carbon footprint, and reduce operating costs. The industrial opportunities for energy efficiency and emissions reductions are even more significant with the substantial improvement in reliability and efficiency of power electronic component technology and the better understanding of areas such as advanced process heating and waste heat recovery.
According to data collected during a DOE Market Assessment survey, more than 13.5 million electric motors of 1 hp or greater convert electricity into useful work in U.S. industrial process operations. Industry buys 20% of all U.S. electricity to operate motor-driven systems. DOE has further estimated that the potential motor system energy savings across all U.S. manufacturing using mature, proven, cost-effective technologies range from 11% to 18% of current annual motor system energy use, or 75 to 122 billion kWh per year. This translates to about $3 billion (U.S.) annual energy cost savings opportunity with existing and new technology. There is ongoing process in improving energy efficiency in thousands of applications, most of them involving electric motors and drives (that is, adjustable speed drives [ASD] or variable frequency drives [VFD]). EPRI and electric utilities are poised to expand that approach and to emphasize new applications of motors leading to productivity improvement.

In this context, there is a need to look at new motors and drive technologies that can increase industrial productivity while consuming less energy, identify barriers and trends in such technologies, develop new tools that can aid industries in optimizing their processes for performance and energy consumption, and develop best practices to improve the reliability of motor-driven systems.

Similarly, in U.S. manufacturing, process heating accounts for over one-fifth of total energy use, making it the largest end use for energy. Process heating is also significant in net electricity consumption in manufacturing, accounting for 12% of the total. As such, improvements in process heating present opportunities to significantly benefit industrial customers through cost reduction and improved productivity while reducing greenhouse gas emissions. There are also other non-energy benefits, such as reduction in physical footprint, associated with the advanced electrotechnologies. For example, the floor space required by a microwave or radio frequency system is 20% to 35% less than that of a conventional heating unit of the same size.

New and advanced process heating technologies and processes are constantly being developed in the United States and overseas countries, but there is a lack of independent evaluation and awareness of these advanced new electric/hybrid (gas and electric, or dual fuel) process heaters and other advanced technologies. Awareness of these advanced technologies—through easy-to-use tools, case studies, and demonstrations of the electrotechnologies—helps industries meet productivity goals and emission targets.

**Approach**

The industrial energy efficiency project will consist of two specific areas of opportunity: 1) motors and drives and 2) process heating. The main objective of this project is to identify new motor and drive technologies and to develop new industry practices that would help U.S. industries improve productivity and competitiveness in the worldwide market while increasing energy savings. On the industrial process heating side, the objective is to create easy-to-use tools to determine energy savings by adapting electrotechnologies, demonstrations, and case studies of efficient process heating technologies, which are not limited to electrotechnology but expand to hybrid dual-fuel technologies.

- **Motors and Drives**: EPRI will update and develop tools (MotorMaster and ASDMaster) for optimizing motor- and ASD-driven processes in U.S. industries, identify barriers and growth trends for new high-efficiency motor and drive technologies such as copper rotor motors, and develop a technical update outlining the most significant issues that often affect motor-drive performance and industrial productivity.

- **Industrial Process Heating**: The project will develop easy-to-use tools that can calculate energy savings and simple pay-back calculations that can assist utility members in switching existing process heating technology with energy-efficient electro- or hybrid (dual-fuel) technology. The technical results outlining the recent advancements in the electrotechnology application in industrial process heating, advantages of electro- and hybrid process heating, and case studies of successful implementations of new process heating technologies will be summarized in the form of a technical brief.
Impact
The industrial energy-efficiency work will result in direct and measurable opportunities in cost savings and help improve U.S. industrial productivity and competitiveness. These impacts will result from several efforts:
- Developing tools for optimizing motor and drive processes
- Identifying new high-efficiency motor and drive technologies and determining any barriers and growth trends
- Developing best-practice recommendations to improve the reliability of motor- and drive-based processes
- Developing simple tools to estimate energy savings and payback calculations for industrial process heating technologies
- Conducting case studies to create awareness of successful implementations of advanced process heating technologies

How to Apply Results
This research will provide application support to utility energy efficiency groups and specialists. The primary application will be tools, technical application documents, and case studies developed under this project.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td><strong>Motors and Drives:</strong></td>
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<tr>
<td>Motors and Drives: A technical update that outlines the most significant issue that often affect motor/drives performance, reliability, and industrial productivity. Update “ASD Master” process optimization tools to include the new EISA 2007 motor legislation as well as new motor and drive technologies. Reference to DOE’s “Motors Master”.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Industrial Process Heating:</strong></td>
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<tr>
<td>Technical brief summarizing the recent advancements in the electrotechnology application in industrial process heating, advantages of electro- and hybrid process heating and case studies of successful implementation of new process heating technologies. Identify developments in new process heating methods in USA and in other overseas countries which will provide valuable information to our member utilities.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

P170.020 High-Performance Homes and Buildings (069239)

Key Research Question
In the United States, buildings account for approximately 40% of total energy consumption and 40% of greenhouse gas emissions. Therefore, improving building energy performance can reduce greenhouse gas emissions more quickly and cost effectively than many other options while helping to address rising energy demand. Moreover, buildings account for about 70% of U.S. electricity use, so improving their energy efficiency can benefit utility capacity, transmission, and distribution operations.

Policy drivers and technology trends are likely to increase market demand for more efficient buildings. DOE, for example, has a federal goal to spur the development of marketable zero-net energy homes and commercial buildings by 2020 and 2025, respectively. California, as an example of a state initiative, has a goal for all new homes and commercial buildings to be zero-net energy by 2020 and 2030, respectively. It is important to differentiate between building segments because each has distinct energy use characteristics.

In 2012, EPR1 will assess two types of building segments: 1) grocery and convenience stores and 2) data centers. The grocery and convenience store segment is addressed as part of an annual series of in-depth assessments, focusing on a different building segment each year. This segment is highly energy intensive, driven by significant refrigeration and space cooling loads as well as lighting. It is also a ubiquitous segment with a presence in every community in the country.
The data center segment is addressed every year in this program, owing to its high energy intensity and enormous growth. Energy use in data centers is projected to grow at the fastest pace of any building segment in the United States. It has doubled in just the past five years, from about 61 billion kWh in 2006—nearly 1.5% of the total electricity use—to more than 120 billion kWh by 2011. Ancillary data center loads, such as cooling and other infrastructure, use as much or more energy than the actual servers that perform computations. In addition, many data centers have reached the limit of their cooling system capacity, which means that they can no longer add servers to the space. With such limits to their productivity, data center operators have a desperate need to address the heat load and improve their building efficiency. The rapid growth of performance in computing and telephony has led to an increased need for bandwidth and data center processing and storage capability. Wide public adoption of technologies such as Internet photograph storage and streaming video will ensure continued growth in this industry. Based on history, new high-performance applications will almost certainly come into vogue, resulting in even more power consumption.

Approach

This project consists of two subsets:

**Zero-Net Energy Grocery/Convenience Stores**: EPRI has undertaken a multiyear effort to create a series of volumes on zero-net energy commercial buildings, organized by building type, that can serve as an encyclopedic reference collection. The first volume in 2011 focuses on large office buildings. The 2012 volume will focus on the grocery and convenience store segment. Future years would focus on other building types, such as apartment buildings, hospitals, retail, lodging, and restaurants. For each type of building, including grocery and convenience stores, EPRI will address the convergence of trends in efficient design, materials, and end-use technologies. Also addressed will be integration with smart grid and energy management systems and on-site renewable generation (for example, photovoltaic) and storage.

**Data Centers**: The data center subset is a continuation of previous years' research to review power and cooling flows in data centers and identify and assess areas in which efficiency gains can be made. Building on this research, recommendations will be made for the most effective measures for energy savings in both cooling systems and the power chain. From these recommendations, and using the metrics developed with the industry, EPRI will help establish performance specifications for individual components, systems, or whole buildings. Members can use these specifications in their energy efficiency programs.

Impact

Project results will help utilities better understand overall energy efficiency opportunities in buildings as well as implications for grid integration. They will also help grocery and convenience store and data center industry customers overcome their biggest problems through technical improvements and standards development. The project results will include the following:

- Establish industry metrics that allow consistent measurement and comparison of energy performance
- Enable customers to use energy (and electricity) more efficiently, thereby enhancing their comfort, productivity, and performance while reducing energy intensity and associated carbon emissions
- Reduce greenhouse gas emissions and contribute to the deferment of capacity additions through energy-efficient operation and use of on-site renewables
- Enable a better understanding of grid integration issues and their impact on capacity and transmission and distribution needs
- Improve economic development by reducing customer facility energy costs
- Improve economic development by reducing utility infrastructure costs
- Enhance facility performance by meeting business needs
How to Apply Results

Project findings and products will be employed by utility account representatives, marketing staff, and energy efficiency specialists as they work closely with their customers in key commercial market segments. Efforts will be aimed at transferring new technologies that can help customers optimize energy use; reduce energy costs; use advanced and intelligent controls for cooling, heating, and other end uses; and produce performance improvements that directly address their comfort and business needs. Establishment of key metrics and specifications will allow member utilities to add data center efficiency measures to their incentive programs. Utility planners and staff engaged in grid integration with zero-net energy buildings will also be able to better understand the infrastructure impacts of such buildings.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Zero-Net Energy Grocery and Convenience Stores</strong>: This project will assess the state-of-the-art in energy efficiency in grocery and convenience stores, leading to zero net energy use in such buildings. It is the second in an annual series of energy efficiency assessments focused on specific commercial building segments. A parallel study on state-of-the-art intelligent buildings in Project Set 170B addresses the same building segment, grocery and convenience stores, in 2012.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Efficient Data Centers</strong>: The project will continue to review power and cooling flows in data centers and identify and assess areas where efficiency gains can be made. Building on this research, recommendations will be made for the most effective measures for energy savings in both the cooling systems and the power chain. From these recommendations, and using the metrics developed with the industry, the Electric Power Research Institute (EPRI) will help to establish performance specifications for individual components, systems, or whole buildings. Members can use these specifications in their energy efficiency programs. In 2011, this project produced a technical update with a comprehensive procedure for calculating energy savings potential using air flow management techniques. The approach is more comprehensive in nature because it includes realistic savings potential for direct expansion air conditioning units in data centers. In 2012, this methodology will be incorporated into an evaluation tool to simplify the job for end users and utilities who wish to include this technology in their programs.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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Future Year Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td><strong>Zero-Net Energy Apartment Buildings</strong>: This project will assess the state-of-the-art in energy efficiency in residential multi-family complexes, leading to zero net energy use by such buildings.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<tr>
<td><strong>Efficient Data Centers</strong></td>
<td>12/31/13</td>
<td>Technical Update</td>
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</table>
P170.021 Electronics, Plug Loads, and Lighting Efficiency (069240)

Key Research Question

Electronics and Plug Loads
The proliferation of consumer electronics is creating dramatic increases in load density that can be offset by efficiency improvements in power electronics, principally power supplies. Examples include gaming consoles such as Xbox 360 or PlayStation® 3, big-screen high-definition liquid crystal display (LCD) and plasma televisions, and Blu-ray Disc™ players. The backbone of these end-use devices is the ac-to-dc power supply. EPA estimates that 1.5 billion power supplies are used in various devices in the United States, constituting about 300 billion kWh, or approximately 11%, of national annual electricity usage. According to DOE's Annual Energy Outlook 2008 report, electricity demand from 2005 to 2030 is projected to grow by 27% in the residential sector, 49% in the commercial sector, and 3% in the industrial sector. These projections dictate that more importance must be given to energy efficiency to achieve sustainable global growth of the digital economy with minimum environmental impact. It should also be noted that these projections are significantly lower than those of 2007 as a direct result of initiatives such as this program. This project undertakes to perform baseline measurements, develop measurement procedures, develop efficiency specifications, and inform policy makers with technical data. Each year is a continuation that includes additional categories of electronic equipment and their power supplies.

Advanced Lighting Technologies
Lighting manufacturers continue to work under pressure to develop new advanced lighting technologies to meet the efficacy requirements of the Energy Independence and Security Act of 2007, while meeting consumers' energy and aesthetic expectations. As the use of incandescent lamps diminishes, advancements in lamp materials, power electronics, and new methods of converting electricity into light are ushering in new and improved technologies for compact fluorescent lamps (CFLs), linear fluorescent lamps, high-intensity discharge (HID) lamps, light-emitting diodes (LEDs), and new hybrid technologies. EPRI will continue to assess, test, and evaluate new electronic lighting technologies and new circuit and lamp designs with regard to their efficacy, compatibility, color and quality, and suitability for various lighting applications.

Approach

Electronics and Plug Loads
This is a multiyear research project, with the focus in 2012 to continue to identify and promote the best-in-class efficiencies for residential and commercial power supply technologies. This project analyzes and evaluates a variety of power supply topologies and architectures used in various common end-use power supplies. Through laboratory and field testing, the best-in-class energy devices available in the market today will be identified. Design changes for efficiency improvements will be developed or suggested in conjunction with vendors. Devices considered for this project include video gaming consoles, gaming computers, high-definition televisions with screen sizes greater than 37 in., Blu-ray Disc™ players, uninterruptible power supply (UPS) systems, and other devices that impact the energy profile in residential and commercial sectors.

Advanced Lighting Technologies
The identification of advanced lighting technologies is carried out by conducting extensive product searches, attending lighting product fairs and conferences, and engaging with existing and new manufacturers of lighting devices. New technologies are procured for testing and evaluation in EPRI's Lighting Laboratory. Lighting research engineers engage in standards efforts in which the standards for new technologies are drafted. Technology evaluation also includes understanding failure mechanisms and defining the reasoning behind breaking performance barriers.
Impact

Electronics and Plug Loads
The efficiency of power supplies affects the energy consumption of nearly all electronic devices. With the growing proliferation of consumer and commercial electronics, efficiency improvements in power supplies will have a profound impact on overall energy consumption in the United States and the world.

Results of this project will allow members to accomplish the following:

- Show leadership in energy efficiency by developing paths to more efficient solutions
- Promote best-in-class efficiency devices to customers, reducing greenhouse gas emissions
- Reduce peak electricity demand, which contributes to the reliability of transmission and distribution networks
- Receive possible tax credits for promoting energy efficiency
- Use valid third-party data to help influence energy efficiency policy through such groups as the Consortium for Energy Efficiency (CEE), California Energy Commission (CEC), and Environmental Protection Agency (EPA)

Advanced Lighting Technologies
Energy and compatibility performance evaluations of new technologies can be used by energy, efficiency, and lighting engineers at utilities to further aid in the decision process before new technologies are added to their approved product listing for energy efficiency, rebate and incentive, and load reduction programs. Those promising technologies will enable high cost-benefit ratios and reasonable payback periods.

Additional value can be realized through the following:

- Understanding the impact on the power system of installing new end-use technologies
- Gaining knowledge regarding the use of lighting technologies that use more digital circuitry
- Understanding which technologies are more favorable for use with lighting controllers and future demand response systems
- Helping to ensure realistic performance that can be matched with product warranty expectations

How to Apply Results

Electronics and Plug Loads
The technical update provides members with knowledge of existing power electronic devices that are best-in-class and that impact peak electricity demands. This document will help personnel in the demand management area promote certain products or product categories that have exceptional efficiency.

Advanced Lighting Technologies
Comparing the electrical, thermal, mechanical, and photometric performance of traditional, fluorescent, HID, LED, and other advanced lighting technologies will allow members to determine when and to what extent they replace traditional lighting in their efficiency rebate and incentive programs. Project results will allow members to determine the effectiveness of using advanced lighting technologies for residential and commercial applications, including those with lighting controllers and demand response systems. Project results will also allow members to determine future energy and power quality requirements for supporting these technologies. Project data will provide a foundation for members to compare field data from future installations with project and demonstration data.
### 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Continuing Efforts for Efficiency Improvements in Electronic Power Conversion Devices:</strong></td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>This project systematically performs baseline testing of product efficiencies to allow recommendations for improvements in design and eventual specifications for higher efficiency. These specifications naturally lead to standards development with policy makers such as the EPA ENERGY STAR program and the California Energy Commission (CEC). These standards will eventually eliminate the availability of inefficient devices in the marketplace. In 2011, the energy savings opportunity assessment for new categories of electronic converters such as smart meters, network devices and uninterruptible power supplies (UPS) were undertaken. In 2012, this work will continue, with an emphasis on more UPS testing. The results will be presented in detail as a technical update.</td>
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<tr>
<th><strong>Advanced Lighting Technologies:</strong> Overview of latest lighting technologies, their efficacies, and system compatibility.</th>
<th>12/31/12</th>
<th>Technical Update</th>
</tr>
</thead>
<tbody>
<tr>
<td>The development of advanced lighting technologies is a continuing effort in the lighting industry. New technologies that are more energy efficient, incorporate advanced light sources, utilize advanced lighting controls, and make use of hybrid technologies are being introduced each year. Compact fluorescent lamps (CFLs), linear fluorescent products, electronic high-intensity discharge (HID) products, light-emitting diode (LED) products, induction products and their derivatives (microHID, organic LED, electroluminescence, etc.) are candidates for this project. The development of such technologies warrants investigation of their design, operation, performance, immunity to power quality, and potential market penetration to keep members informed.</td>
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</table>

| **Assessment of Solar Daylighting Technologies:** Overview of new solar daylighting technologies, their designs, and photometric performance. The development of solar daylighting technologies is a continuing effort in the building and lighting industries. New technologies that capture the sun’s energy, transfer it to interior spaces using different techniques, and make use of various optical delivery elements are being introduced every 2-3 years. These include roof-mount collectors, solar concentrators, and skylights among others. The development of such technologies used to augment electric lighting warrants a joint project between Electric Power Research Institute (EPRI) and the California Lighting Technology Center (CLTC) to carry out investigations into their design, effectiveness, and potential market penetration. | 12/31/12 | Technical Update   |

### Supplemental Projects

#### Industrial Center of Excellence (069621)

**Background, Objectives, and New Learnings**

The objective of this work scope is to further develop and staff the EPRI Industrial Center of Excellence (ICoE) for industrial technologies, processes, and applications. This will include the interactions necessary to leverage key industry relationships, state-of-the-art supporting facilities, and subject matter experts. The Industrial Center of Excellence will continue to be web based and intends to leverage the best laboratories, contractors, and universities having core competencies and expertise in energy utilization and environmental controls. It is anticipated that as member interest grows, the Center will grow along with that interest and this work will evolve into a long-range effort.
New learning from this project will include improved understanding of the needs of industry in the process heating and waste heat recovery areas, as well as insights on new technologies available to meet these needs. Public benefit of this research will include better access to resources for industrial energy users and improved ability of electric utilities to retain jobs and economic vitality for the communities they serve. All new learning from this research is expected to be published to the public and provide public benefits through increased energy utilization opportunities.

Project Approach and Summary

The proposed new roles for the EPRI Industrial Center of Excellence in 2012 will be as follows:

- Develop and apply industrial energy efficiency and power quality (PQ) auditing as industry resources, enabling direct assistance by utilities to key customers and affording a practical setting for both learning and applying lessons learned.
- Develop additional knowledge resources for technology- and industry-specific categories, including classic, thermal, and electro-technology opportunities.
- Continue to develop an enhanced understanding of the role electric utilities can and should play in the ISO 50001 and Superior Energy Performance (SEP) standards. ISO 50001 offers a standardized framework by which a diversity of facilities—industrial, commercial, and institutional—can establish validated policies and procedures to manage energy use and increase productivity. Approximately 60% of commercial and industrial energy use is expected to fall under the standard’s purview, affording utilities a significant opportunity to provide direct value to key customers and to enhance the utility’s role as a value-added provider. Compliance with the ISO 50001 standard is the core element of SEP, which will be included as part of this research.

Benefits

EPRI’s Industrial Center of Excellence was established to encourage specific energy- and technology-related developments. Using EPRI, utility, and industry subject matter expertise, the Center supports knowledge transfer and applications and seeks to identify opportunities for demonstrations and commercialization of advanced efficient electric technologies and utilization methods. The Industrial Center of Excellence supports members and their customers through testing, training, education, and outreach.

Energy Efficiency Demonstration 2.0 (072091)

Background, Objectives, and New Learnings

A strategic way to meet consumer demand for electricity is to increase the efficiency of the use of electricity. Investments in enhancing end-use energy efficiency, such as advancing efficient end-use technologies, can offer substantial return to consumers, society, and utilities. EPRI and others help advance efficient end-use technologies through a technology development pipeline beginning with scouting for emerging technologies, conducting assessments and laboratory testing on the most promising technologies, and proceeding to field demonstrations of the highest potential technologies. EPRI and its members launched the first Energy Efficiency Demonstration in 2009 to provide this critical step in the advancement of emerging end-use technologies by demonstrating "hyper-efficient" technologies in residential and commercial settings.

This project, Energy Efficiency Demonstration 2.0, builds on the success of the first demonstration project and provides an opportunity to demonstrate the next round of hyper-efficient end-use technologies. As such, consideration will be given to technologies that have been developed on a worldwide basis. The project could lay the groundwork for understanding the technical and other obstacles for adopting many of the new hyper-efficient technologies, which could lead to a substantial reduction in electricity consumption for several major end uses of electricity. Technologies demonstrated under this program have the potential for early deployment in the next stage of the pipeline, EPRI’s Coordinated Early Deployments of Efficient End-Use Technologies program.
**Project Approach and Summary**

Demonstrations are needed to verify performance, understand technical issues, and validate applicability in commercial and residential buildings and locations such as parking lots and streets. Issues that need to be resolved include verifying energy and demand savings, adapting service voltages and frequency, verifying electromagnetic compatibility, and ensuring power quality and customer acceptance.

The technologies will be demonstrated with several utilities using different selection criteria such as climate, population density, and regulatory restrictions to assess their performance when deployed in diverse environments. Using a disciplined process for screening technologies to determine appropriate treatment, EPRI will select four to six new technologies not already covered in the initial Energy Efficiency Demonstration. Collaborators are encouraged to participate in the selection process. Some early candidate technologies include advanced dehumidification systems, evaporative cooling, plasma lighting, dimmable HID lighting, induction lighting, and smart power strips. Technologies are not limited to residential and commercial but may include industrial applications. The demonstration will evaluate the performance of hyper-efficient technologies at multiple utility sites.

The project will strive to achieve the following objectives:

- Examine the efficiency and performance of the technologies
- Assess energy savings for different climatic regions, building designs, and constructions
- Identify and quantify different qualities and effects when compared with traditional technology
- Identify changes necessary in building designs and construction to attain optimum levels of energy performance and savings
- Understand technical obstacles such as the possible impact of the technologies on the performance of the electric grid
- Examine the feasibility of applying desktop computer power supply efficiency standards to large-scale computer power systems operated in data centers.

**Benefits**

The benefits of demonstrating hyper-efficient end-use technologies include the following:

- Advancement of hyper-efficient end-use technologies toward readiness for energy efficiency programs
- Enhancement of your team’s understanding of the strengths and challenges of hyper-efficient technologies
- Reduced costs and risks of demonstrating hyper-efficient technologies by collaborating and using EPRI’s proven field demonstration process

Collectively, the technologies selected will have the potential to reduce the consumption of electricity by more than 10%, reducing the need for new generation capacity. With the support of participants and engagement with manufacturers and industry groups, EPRI will help understand the obstacles that impede the adoption of hyper-efficient technologies.

**End-Use Load Shape Library - Phase 2 (072092)**

**Background, Objectives, and New Learnings**

End-use load research data are useful to utilities for numerous activities such as load forecasting, energy efficiency and demand response program design, and resource planning. Several studies were conducted 20–30 years ago and form the basis of most end-use data analysis today. However, the development of new technologies, pricing programs, efficiency standards, and rebate programs has combined to produce significant changes in end-use loads and load shapes. This effort would rectify those data shortcomings by developing a national end-use load research program. Reduced costs of collecting interval data through smart meter and advanced metering technologies are the catalyst for this effort.
Project Approach and Summary

This project would use the results of Phase I to collect and analyze residential end-use load data. The Phase I project will investigate alternative cost-effective methods for collecting end-use data. These include conditional demand analysis, non-intrusive load monitoring and smart distribution panels among others. Phase II would be the collection and analysis phase and would collect residential end-use load data on a broad geographic and climate zone basis.

Benefits

Better household and end-use load-shape data would greatly benefit load forecasters, system planners, energy efficiency program managers, and rate design analysts. More detailed and accurate end-use information would help identify the drivers of system load shapes and improve the understanding of which loads could be shifted to off-peak hours, which could both lower fuel costs and increase the use of renewable technologies (for example, wind that blows at night when loads today are typically at their lowest levels). This information would be useful for energy efficiency and demand response program design and help identify the need for improved communication and control technologies that would facilitate the integration of demand and supply options.
Understanding Electric Utility Customers - Program 182

Program Overview

Program Description

Understanding what customers want and how they perceive and realize value from electric services is becoming more important—in some cases, imminently so. There is a growing movement for electric utilities to better understand, as well as engage with, customers so that they may more fully realize the benefits of utility program activity and technology investments.

Other industries have been developing detailed knowledge of their customers’ preferences and behaviors for decades. Obtaining customer intelligence has been an important element of utility operations as well, but the focus has been more directed to measuring customer satisfaction rather than developing an in-depth understanding of when and how they use electricity. Utilities today are grappling with the knowledge that the customer will play a pivotal role in ensuring a link between technology deployments and the investment benefits that are to be realized.

With new technologies being added to the grid to enable greater consumer participation in how they manage their electricity usage, there is an opportunity for the electric utility industry to get customers actively and sustainably involved in electricity usage decisions. However, some fundamental research is first required to get to the root of various aspects of utility customer behavior, such as the effects of rate structure and information provision (or feedback) on customer response, response variation by customer segment, and other pertinent research questions.

Research Value

Although research is already ongoing in some of these areas, an opportunity exists to make it more collaborative and probing, while at the same time more extensible to circumstances beyond just those of individual jurisdictions. Transparency and research rigor also may be bolstered by making data available to a wider research audience, a practice not typically followed in the industry. The Electric Power Research Institute’s (EPRI’s) collaborative research model is uniquely qualified to capitalize on these opportunities.

Approach

The Understanding Electric Utility Customers research program is comprised of two project sets: 1) Impacts of Rates and Pricing Structures and 2) Customer Behavior. These areas will complement EPRI’s ongoing technology research, so that together the three areas of technology, pricing, and behavior will more fully encompass the range of utility research needs, and EPRI and its members will develop a foundation of knowledge that will help guide investment decisions that can help move the industry forward.

With this program, members will have access to information that can help them in these ways:

- A rate structure design manual that combines conceptual guidance from the disciplines of finance and economics with real-world experience about how customers respond to different rate structures
- A framework for designing wholesale and retail markets to foster the optimal demand response
- Facilitating the use of behavioral programs to tap into new sources of savings potential by assessing the appropriateness of using a deemed savings approach for estimating savings
- New approaches to understanding customer diversity by building robust and reliable customer groupings and associations
Accomplishments
Past customer-facing work has previously taken place under Program 170 (Energy Efficiency and Demand Response), Program 18 (Electric Transportation), and the Smart Grid Demonstration Project. These include the development of feedback research design protocols, plug-in hybrid electric vehicle (PHEV) customer preference surveys, and various smart grid demonstration behavioral pilot designs.

Current Year Activities
Through a 2011 supplemental project, utilities will participate in two workshops, each of which will result in a white paper. The objective of these activities is to stimulate new ideas and new thinking around the topics of rate and pricing structures and understanding how consumers value and use electricity—two topics that map directly to the two project sets of Program 182. It is expected that this research also will facilitate the process of generating ideas that will help shape the content of the new program in 2012.

Estimated 2012 Program Funding
$1.8M

Program Manager
Bernard Neenan, 865-218-8133, bneenan@epri.com

Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>P182.001</td>
<td>Assessment of Rate Structure Options</td>
<td>The development of a rate structure design manual that incorporates the concepts, tools, protocols, and experience-based data needed by utilities to design rates that achieve predictable and desirable outcomes</td>
</tr>
<tr>
<td>P182.002</td>
<td>Linking Wholesale and Retail Markets to Achieve the Full Benefits of Demand Response</td>
<td>The development of a complete and detailed characterization of how demand response influences wholesale and retail electricity markets and the creation of a means for quantifying the level and distribution of impacts that result from offering demand response as a retail choice or as a system resource</td>
</tr>
<tr>
<td>P182.003</td>
<td>Deemed Savings for Behavioral Programs</td>
<td>This project intends to identity and assess the factors for consideration in the development of pre-determined or deemed saving estimates for behavioral programs, as well as propose a set of metrics and performance standards necessary for industry acceptance of such estimates.</td>
</tr>
<tr>
<td>P182.004</td>
<td>Characterizing Customer Diversity</td>
<td>Develop approaches for sorting customers according to measurable attributes that are associated with energy usage, and provide guidance for using these associations as a basis for communicating information, incentives, and offers to different customer types</td>
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</table>
P182.001 Assessment of Rate Structure Options (072117)

Key Research Question
A wide assortment of alternative structures is available to price electricity. The relative effectiveness of many alternative pricing structures in achieving specific goals (for example, efficiency, fairness, load shifting, conservations, and societal goals) has not been clearly and concisely defined. This is especially true of dynamic pricing and demand response structures that have rather narrowly constructed objectives, the attainment of which has not been thoroughly or unequivocally established. Utilities often are faced with needing to achieve a specified goal, or set of goals, without a way to determine what price structures are best suited to accomplish the desired result or a good understanding of the revenue implications of migrating customers from one rate structure to another.

Moreover, how customers respond to price structures is not well established, especially for dynamic pricing and demand response structures that are receiving more attention because they can address particular and vexing market imbalance situations.

EPRI intends to develop the concepts, tools, protocols, and experience-based data needed by utilities to design rates that achieve predictable and desirable outcomes. The result will be a rate structure design manual that combines conceptual guidance from the disciplines of finance and economics with real-world experience about how customers respond to rate structures.

Approach

- Conceptual foundation: EPRI will use and expand upon the rate structure framework development undertaken in previous EPRI research (P170). That framework provides a comparison of how the higher-order classes of rate structures achieve various and often competing goals.
- Comparative framework: This project will develop a more detailed characterization of the expected impacts of alternative rate structures that can support designing rates for all classes of customers, applicable to at all levels of the sector (wholesale and retail), in all supply circumstances (short-run expediency and long-run sustainability).
- Design tools and protocols: Develop analytical methods and protocols for their application to specific rate structure design objectives that allow the designer to construct one or several rate structures, among other things.

Impact

- A comprehensive design tool kit will help utilities implement a pricing structure, or portfolio of pricing structures, that are aligned with the goals that drive the initiative, undertake the initiatives with a high chance of success, and track achievements regularly and reliably.
- Through the use of a standardized design process, other utilities gain from the collective knowledge that results about what works in rate structures, how well it works, and in what circumstances.

How to Apply Results

- Assess and quantify changes to existing rate structures
- Design and evaluate purpose-specific rate structures, such as low income, economic development, peak shaving, and load shifting
- Quantify the expected benefits from smart-grid–enabled pricing structures
- Develop and evaluate a portfolio of offerings made available through opt-in or opt-out implementation and administration
P182.002 Linking Wholesale and Retail Markets to Achieve the Full Benefits of Demand Response (072118)

Key Research Question

Opportunities for direct customer participation in wholesale electricity markets (capacity, energy, and ancillary services) are increasing. This is in part the result of concerns that retail markets are not providing customers with enough, or the right, opportunities to realize greater value by making consumption decisions based on the prevailing or implicit cost of supply. Demand response is important because it promotes the efficient utilization of societal resources. However, wholesale programs may be substitutes for, and instead of complements to, retail programs because the value propositions are not properly aligned. That may lead to demand response service and programs being limited to what serves the wholesale market’s needs. The interface between wholesale and retail electric market operations is of critical importance, but has been given only limited research attention. Realizing the full advantages of demand response requires characterizing that interface, identifying seams that disrupt the flow of efficient pricing or other load-influencing signals back and forth, and then devising programs and service that define an efficient interface.

The objectives of this project are to develop a complete and detailed characterization of how demand response influences wholesale and retail electricity markets and a means for quantifying the level and distribution of impacts that result from offering demand response as a retail choice or as a system resource.

New learnings will include the establishment of the direct and indirect linkages between changes in electricity usage by customers, regardless of how they are induced, and the performance of the electricity sector. Metrics to measure the level and distribution of net benefits from demand response that takes into account how it was induced also will be included.

Approach

- Develop a complete and detailed characterization of how demand response influences wholesale and retail electricity markets
- Construct the means for quantifying the level and distribution of relative benefits that can be expected to result from the implementation of wholesale and retail programs

Impact

- A framework for designing wholesale and retail markets to foster the optimal demand response
- Objective quantification of the value of demand response
- Demand response forecasting tools
- Design tools to support the development and implementation of demand response programs and pricing structures

How to Apply Results

- Utilities can design more effective and customer-accepted rate structures.
- Wholesale markets will be able to anticipate and account for retail demand response to realize the benefits in system dispatch.
2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td><strong>Impacts of Demand Response on Wholesale and Retail Markets:</strong> A detailed characterization of how demand response influences wholesale and retail electricity markets and a methodology for quantifying the level and distribution of benefits from demand response</td>
<td>12/31/12</td>
<td>Technical Report</td>
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P182.003 Deemed Savings for Behavioral Programs (072119)

**Key Research Question**

For several technology- and device-oriented energy efficiency programs, industry-accepted deemed savings values (or algorithms) have been adopted to calculate expected overall program savings under a wide range of circumstances.

Most behavioral programs, defined as those efforts to influence retail customers with respect to how they use electricity, have not matured to the level of enjoying such deemed savings values. Moreover, program impacts depend entirely on human behavior, which can vary and may not necessarily be fixed for any specified duration. Pilot test results indicate that behavioral interventions can induce changes in consumption behavior among residential customers. But research into behavioral strategies is just now reaching the formative stage, and the persistence of those consumption patterns and levels has not been demonstrated completely.

The objectives of this project are to establish and propose the metrics and performance standards necessary for the industry to accept pre-determined or deemed consumer electricity use changes attributable to behavioral programs.

New learnings are expected to include a comprehensive understanding of how customers associate value, financial or otherwise, to electric services, as well as understanding behavioral models and derivative mechanisms that establish a measurable relationship between program inducements and behavioral responses over time.

**Approach**

- This project will identify the concept of deemed savings estimates, which are generally accepted for specific technology-based energy efficiency programs, to ascertain what elements are transferrable and what aspects must be developed.
- This will involve developing a definition for deemed savings as it would relate to different types of behavioral programs. This would be done by identifying the opportunities and limitations to such an approach, and, if appropriate, highlighting the empirical research that would need to take place to overcome the limitations.

**Impact**

- Deemed savings metrics for behavioral programs may save utilities time and money in constructing and assessing alternative program initiatives.
- May facilitate the use of behavioral programs as a new wellspring of energy savings to achieve utility savings goals.
How to Apply Results

- Refine and revise energy efficiency program designs to consider behavioral programs as complements to device efficiency measures
- Incorporate the methods and metrics developed into utility resource planning processes to broaden the options available to provide reliable and affordable electricity
- Merge the findings with those that flow from the research to characterize how customers respond to alternative pricing structures

2012 Products

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<tr>
<td>Deemed Savings for Behavioral Programs: Considerations and Requirements for Industry Acceptance: A detailed analysis of what would be necessary to move towards the usage of deemed savings estimates for behavioral programs and the challenges and opportunities associated with such an approach</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
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P182.004 Characterizing Customer Diversity (072122)

Key Research Question

Many smart grid investments enable, but do not obligate, customers to use electricity differently. There exists the opportunity for customers to be involved in new ways for prospective benefits to be realized. But utility customers vary with respect to their needs and preferences and, as such, utilities are seeking to understand how different elements of their customer base respond to different technology and program offerings.

The objectives of this project are to develop methods for sorting customers according to measurable attributes (for example, volunteer/participation rate, purchase behavior, information content preferences, and demographics) that are associated with energy usage. These associations, which are sometimes called segments or communities of interest, provide a foundation for the effective conveyance of information, incentives, and offers with various groups of customers.

This project will provide new insights on differences among customer groups in how information and incentives are processed, interpreted, and acted upon.

Approach

- Review methods for building association from a variety of behavioral disciplines, such as psychology, sociology, economics, statistics, and others
- Synthesize evidence of customer response variation in a range of categories including the following:
  - Information content and aesthetics: how do different people understand and value information about their electricity usage
  - Uptake rates for different energy efficiency and demand response programs
  - Purchase behavior of different energy efficiency technologies
- Review commercially available customer segmentation tools, and categorize them according to the grouping association premise they are based on
- Identify opportunities for using interval meter and appliance-level data to characterize and understand customer variation, and propose ways for how these data might be used in conjunction with other targeting methods
Impact

- Building robust and reliable customer groupings and associations
- Reduce the cost and improve the effectiveness of information and message delivery activities
- Conduct target marketing and promotion to achieve distinct objectives such as energy efficiency measure adoption and demand response participation

How to Apply Results

- Educate staff on what factors serve as key distinctions in communicating with customers
- Employ learnings and specific methods to customer communications initiatives
- Consider diversifying service offerings to meet customer wants and needs

2012 Products

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<tr>
<td>To Each His or Her Own: Approaches for Distinguishing Electric Utility Customer Differences: Approaches for sorting customers according to measurable attributes that are associated with energy usage and for providing guidance for applying such methods to target customers for better achieving savings and satisfaction goals</td>
<td>12/31/12</td>
<td>Technical Report</td>
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Supplemental Projects

Application of Rate Structure Design (072125)

Background, Objectives, and New Learnings

Under the base program, EPRI will develop protocols and tools for matching rate structures with utility and the society's objectives and test them with sample data. Their value will be determined ultimately by how well they perform in realistic circumstances. This supplemental will involve cases studies undertaken with utilities to demonstrate how the tools work in applications that approximate how utilities design, test the efficiency of, and select rate structures for implementation.

Demonstrating the applications of the design protocols and tools under realistic circumstances will expose any conceptual shortcomings so that they may be remedied; show how they interface with utility data systems and existing rate design tools and practices; and build confidence and acceptance in their use as a result of case study documentation. Such demonstrations are a necessary precursor to the use of the tools and protocols in practice for commercial and regulatory purposes, which in turn is a stepping stone to wide-scale acceptance of the characterization of rate structures. Utilities, regulators, and customers will benefit equally from standardized, credible, and robust characterizations of the impact of alternative rate structures that accelerate the diversification and modernization of electricity services.

Project Approach and Summary

EPRI will help utilities apply the rate structure framework and design tools to their specific market and customer circumstances to demonstrate how the methods are applied and provide experience in the use of the design tools. Applications can be tailored to focus on a specific rate structure for general applications, exploring the differences in impacts for a family of rate structures with common elements, developing a portfolio of rate options, or other utility areas of research interest.

Benefits

- The design protocols will ensure that utilities implement a pricing structure or structures that are align with the goals that drive the initiative, undertake the initiative with a high chance of success, and provide for a plan to track achievement of goals regularly and reliably.
- Utilities and the public gain from the collective knowledge the findings provide on relationship between rate structures and consumer behavior.
Consumer Survey Development and Application (072126)

Background, Objectives, and New Learnings

A key element of understanding customers is to develop channels for collecting information directly from them. Typically, utilities develop survey instruments individually to collect data associated with relatively tightly circumscribed areas of interest, using techniques that serve the immediate need but do not always conform to protocols and scientific methods that make the data useful for other purposes by the utility, or for similar purposes by others. This can result in redundant activities that produce data that cannot be generalized. A coordinated effort to develop multi-purpose survey instruments and associated analytical tools will speed up the acquisition of robust data sets required to characterize electricity customers and provide retail products and services that fill explicit demands while improving the efficiency of the electricity sector.

The objective of this project is to develop consumer preference survey guidelines and survey instrument templates to assess customer perceptions of technologies and/or utility program offerings, tailor the instruments for specific utility circumstances (for example, to assess perceptions of utility-specific technologies or program offerings), and field the surveys across one or multiple utility jurisdictions.

This project will provide new insights into customer preferences regarding technology/program offerings in specific jurisdictions, as well as the ability to look for trends and variations across jurisdictions.

Project Approach and Summary

EPRI will work with participating utilities to apply the survey guidelines and adapt the instruments to the specific technology/program offering, as well as develop utility-specific sections to gain insights where appropriate. Other utilities can sign on to the project at later times as appropriate. Each utility will field the survey in their jurisdiction, and EPRI will perform both utility-specific and pooled results analyses.

Benefits

- Survey development at a lower cost through the collaborative research process.
- The public will benefit by being able to pool survey data to create a rich and robust research database that may support a wide variety of research into characterizing customer needs and preferences.
Power Quality - Program 1

Program Overview

Program Description
Electric utilities worldwide consistently report that power quality (PQ) is a fundamental component of the three key utility business performance metrics: system performance, economic performance, and customer satisfaction. By applying EPRI's extensive PQ expertise, the Power Quality research program may help to improve these three metrics, allowing PQ managers and transmission and distribution (T&D) asset utilization and system planning professionals to use PQ-related technology, knowledge, and expertise to help improve their organization's bottom-line performance.

Research Value
With the knowledge acquired through this research program, members will have access to information that can help them in the following ways:

- The program is developing ways to estimate future grid PQ harmonics and other PQ levels (Grid-IQ Framework, Project Set 1A) based on changing grid configurations and load behaviors, which may allow improved estimation of future PQ levels on modern utility systems. The program is addressing this goal by developing a library of open-source grid models and conducting structured analyses of future PQ levels.
- The program is creating a library of end-use and distributed energy resources (DER) models (Project Set 1C), which may allow assessment of the PQ impact of different and changing load configurations. The program is addressing this goal by updating existing end-use models and developing new ones based on laboratory testing at EPRI facilities.
- The program is developing the PQ Investigator (Project Set 1C), which is intended to capture EPRI expertise in end-use investigations in an expert system that may allow expedited and thorough investigation, diagnosis, and documentation of end-use PQ issues.
- The program is applying models and tools to improve benchmarking of system performance (Project Set 1A). The program is addressing this goal by developing updated benchmarking methods based on more robust PQ severity metrics and experience from previous EPRI studies.
- The program is in the forefront of helping modern utilities cope with the "data tsunami," which will make the integration of data from many different sources very attractive. The program is addressing this goal by developing methods for integrating data streams from a variety of sources, including relays, smart meters, and others (Project Set 1B).
- The program is identifying ways to apply PQ data and other data sources to detect incipient faults and equipment failures and assess equipment health and overall system performance (Project Set 1B). The program is addressing this goal by developing methodologies for identifying key signature characteristics in PQ data.
- The program is supporting the development of key industry standards that may increase compatibility between electric power and customer loads. The program is addressing this goal through active support in International Electrotechnical Commission (IEC) and Institute for Electrical and Electronics Engineers (IEEE) standards committees, including IEEE 1648 (Project Set 1C).
- The program is providing direct support of funder PQ teams. The program is addressing this goal through access to over 50 PQ experts on EPRI's staff via the EPRI PQ Hotline (Supplemental PS1D).

Approach
EPRI research in power quality will yield a variety of data and knowledge that will be beneficial to program members. This information will be offered in several forms and is expected to include the following:

- The MyPQ.epri.com website
- Software updates
Accomplishments

In the past, the Power Quality program has delivered valuable information that has helped its members and the industry. The following are some examples:

- EPRI has created the first open-source-based grid model database to allow the structured estimation of future grid harmonics and other PQ levels.
- EPRI's laboratory testing of many end-use technologies has enabled the development of a detailed load model library for new and changing loads such as compact fluorescent lamps (CFLs), light-emitting diode (LED) traffic lights, hybrid electric vehicle chargers, and rooftop photovoltaics (PV).
- EPRI's Integrated Power Quality Diagnostic System (IPQDS) is a compilation of tools that allows PQ engineers to perform basic power quality analyses such as transient and harmonics analysis, voltage sag simulations, and motor-starting calculations. This report discusses three specific IPQDS modules—the capacitor switching module, flicker analysis module, and motor-starting module—as well as the tap fusing worksheet, a Microsoft Excel spreadsheet.
- The PQ Investigator combines the expertise of over a decade of PQ auditing and site surveys to give power quality engineers an expert system for diagnosing, solving, and documenting PQ issues for commercial and industrial customers. The web-based approach offers investigators a powerful, easy-to-use format.
- Many of EPRI's past research developments have been implemented over time into PQView®, a multi-component software system jointly developed by EPRI and Electrotek Concepts for building and analyzing databases of power quality and energy measurements.
- The Power Quality Online Resource Center is a member-focused website with the latest information on events, program deliverables, PQView software downloads, power quality tools, and more.

Current Year Activities

In the coming year, this research program expects to accomplish these objectives:

- Expand the Grid-IQ grid model library and incorporate new load models.
- Apply the Grid-IQ Framework to predict harmonics and other PQ levels for a variety of grid and load configurations.
- Update techniques for benchmarking grid power quality, especially harmonics levels.
- Enhance techniques for applying PQ and other data sources such as improved data-based fault location techniques, equipment failure (or near-failure) detection, and grid diagnostics.
- Develop new techniques for integrating data from multiple sources.
- Update PQ Investigator, incorporating the latest equipment sensitivity and mitigation performance curves and PQ monitoring data import functions. Add Investigator functionality to build custom PQ audit cases, solutions, economics, and reporting functions.
- Assess the PQ contribution of new or changing loads such as CFLs, rooftop solar inverters, and hybrid electric vehicle chargers.
- Enhance the MyPQ.epri.com website, including additional technical resources for the PQ Online Resource Center comprising more than 500 documents.
- Expand the PQ Newsletter capability, including the addition of new articles, newsletter templates, and online tools.
- Provide quality assurance testing of PQView and opportunities for enhancement through focused projects based on input from the PQView Users Group and members.

Estimated 2012 Program Funding

$2.4M
Summary of Projects

PS1A Improving PQ in Transmission and Distribution (062088)

Project Set Description
The Improving PQ in Transmission and Distribution Project Set is developing the Grid-IQ Framework, which combines a growing library of grid models, testing-based models for new loads and other grid-connected devices, and query engines to allow the prediction of future PQ performance under varying scenarios. This project set is also developing new models and tools for improving system performance benchmarking by updating benchmarking methods based on experience from previous EPRI studies.

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>P1.001</td>
<td>PQ Issues and Solutions for Transmission and Distribution</td>
<td>This ongoing project builds on years of research and application guide development, drawing on the PQ expertise of EPRI as well as that of project members. The project builds on the Grid-IQ Framework developed in P1.003 and represents the practical application of that research.</td>
</tr>
<tr>
<td>P1.002</td>
<td>PQ Benchmarking and Standards</td>
<td>Work planned for 2012 includes capturing key actionable conclusions from the TPQ/DPQ III project, a combined distribution and transmission power quality benchmarking study. This study will move beyond EPRI’s previous benchmarking studies by developing the infrastructure to automatically collect and benchmark data. This work will begin to inform future standards that presently use PQ and reliability metrics and provide more useful, precise information for the various T&amp;D voltage classifications for those standards and for comparative benchmark efforts.</td>
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<tr>
<td>P1.003</td>
<td>Support and Development of PQ Analysis Tools</td>
<td>This project will continue the development of an open-source grid model library (Grid-IQ Framework) to enable the estimation of future grid harmonics and other PQ levels. The Grid-IQ Framework combines a growing library of grid models, testing-based models for new loads and other grid-connected devices, and query engines to allow the prediction of future PQ performance under varying scenarios.</td>
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</table>

P1.001 PQ Issues and Solutions for Transmission and Distribution (055700)

Key Research Question
Management of power quality is a key core competency for electrical transmission and distribution systems around the world. Power quality issues on the T&D system are often complex, wide reaching, and expensive to mitigate. Increasingly, utilities have been trying to assess future PQ levels for their T&D systems but are finding few resources.

Approach
This project focuses on developing and executing techniques for estimating future grid harmonics and other PQ levels through the application of grid models based on changing grid configurations and end-use loads.
Work in 2011 will focus on:

- Assessing future harmonics levels based on changing grid configurations and end-use loads
- Modeling the grid impact of new or changing loads such as CFLs, rooftop solar inverters, and hybrid electric vehicle chargers as prioritized by members

**Impact**

- Models and predicts future PQ levels (especially harmonics) using actual grid and load models
- Predicts future PQ levels, allowing members to anticipate, manage, and prevent grid issues

**How to Apply Results**

Power quality and T&D engineering, design, operations, and maintenance professionals can best apply the results of this research by assimilating them prior to undertaking investigation or mitigation of a PQ issue on the T&D system.

**2012 Products**

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Modeling of Future Harmonics Levels on T&amp;D Grids:</strong> This ongoing project builds on years of research and application guide development, drawing on the PQ expertise of EPRI as well as that of project members. The project builds on the Grid-IQ Framework developed in P1.003 and represents practical application of that research.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>

**P1.002 PQ Benchmarking and Standards (058585)**

**Key Research Question**

Reporting PQ performance is a critical requirement for electric utilities in informing internal planning processes, enabling performance benchmarking, and accommodating external reviews required by regulators. Benchmarking of existing PQ standards offers opportunities for improved system performance at reduced capital cost.

**Approach**

This project area provides tools and guidelines for effective performance assessment and reporting methods. It helps members better understand and adopt industry standard approaches for performance assessment and provides coordination with new industry standards development. The project will track and contribute to industry standards development related to PQ and reliability indices and reporting methods. It will also develop tools and advanced methods for analyzing system performance as a way to help improve performance. These tools and methods include advanced approaches such as the service quality index pioneered in this program, statistical characterization methods, and methods for normalizing performance according to system characteristics (for example, lightning).

The project will also track regulatory issues and standards development around the world to understand priorities for benchmarking and characterizing performance. New methods for applying statistical characterization methods and normalizing results will be documented and addressed in an annual workshop on reliability and PQ benchmarking developments.

Work planned for 2012 includes capturing key actionable conclusions from the TPQ/DPQ III project, a combined distribution and transmission power quality benchmarking study. This study will move beyond EPRI's previous benchmarking studies by developing the infrastructure to automatically collect and benchmark data.
**Impact**

- Helps members effectively apply industry standard methods for characterizing performance, which can significantly reduce the cost of these activities
- Provides advanced system performance measures to help provide a better basis for making system performance improvement investment decisions, improving the cost-benefit ratio of these activities.

**How to Apply Results**

Power quality and T&D engineering, design, operations, and maintenance professionals can best apply the results of this research by assimilating them and applying them to recommended PQ and reliability characterization and reporting methods in their external reviews of—and internal planning for—reliability and power quality performance.

**2012 Products**

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<th>Product Title &amp; Description</th>
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<tr>
<td><strong>Power Quality Benchmark Results and Analytical Tools:</strong> Work planned for 2012 includes capturing key actionable conclusions from the TPQ/DPQ III project, a combined distribution and transmission power quality benchmarking study. This study will move beyond EPRI's previous benchmarking studies by developing the infrastructure to automatically collect and benchmark data. This work will begin to inform future standards that presently utilize PQ and reliability metrics, and provide more useful and precise information for the various T&amp;D voltage classifications for those standards and for comparative benchmark efforts.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>

**P1.003 Support and Development of PQ Analysis Tools (048303)**

**Key Research Question**

Expert software resources for PQ are difficult to find in the industry, but they are essential for understanding complex phenomena and cost-effective problem solving. The time and cost of developing these tools are prohibitive, and the technical expertise required to create them can be difficult to find.

**Approach**

This project will continue the development of an open-source grid model library (Grid-IQ Framework) to enable the estimation of future grid harmonics and other PQ levels. The Grid-IQ Framework combines a growing library of grid models, testing-based models for new loads and other grid-connected devices, and query engines to allow the prediction of future PQ performance under varying scenarios.

**Impact**

- Expands the grid model library and incorporates new load models
- Applies the Grid-IQ Framework to estimate future harmonics and other PQ levels for a variety of grid and load configurations

**How to Apply Results**

Power quality and T&D engineering, design, operations, and maintenance professionals can best apply the results of this research by assimilating them and applying Grid-IQ as part of their grid management and planning strategies.
2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tr>
<td>Grid-IQ Framework: This project will continue development of the an open-source grid model library (Grid-IQ Framework) to enable estimation of future grid harmonics and other PQ levels. The Grid-IQ Framework combines a growing library of grid models, testing-based models for new loads and other grid-connected devices, and query engines to allow prediction of future PQ performance under varying scenarios.</td>
<td>12/31/12</td>
<td>Assembled Package</td>
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</table>

PS1B Integrating PQ Monitoring and Intelligent Applications to Maximize System Performance (062089)

Project Set Description

This project set focuses on techniques and resources for gathering, storing, analyzing, and visualizing many types of data, in particular, PQ data. The project set provides for quality assurance testing of PQView®, a multi-component software system jointly owned by EPRI and Electrotek Concepts, for building and analyzing databases of power quality and energy measurements. Its components build measurement databases, write summary reports, compute power quality indices, view waveforms and root-mean-square (rms) samples, and trend steady-state quantities.

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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P1.004</td>
<td>Integration of Data from Multiple Sources</td>
<td>This project integrates PQ and system data from multiple and federated sources to enable improved decision making.</td>
</tr>
<tr>
<td>P1.005</td>
<td>Advanced Applications for Monitoring Systems</td>
<td>This project expands the value of PQ monitoring systems by using the data to develop important information about the health of the overall system and individual components.</td>
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</tbody>
</table>
| P1.006 | Monitoring System Development and Management | • Advanced features and capabilities for managing and analyzing PQ data and large power quality monitoring databases  
• EPRI quality assurance testing of PQView gives funders access to software with additional validation. |

P1.004 Integration of Data from Multiple Sources (060443)

Key Research Question

The EPRI PQ program has identified issues relating to PQ data and monitoring as important to the success of electric utilities in the coming years. One challenge is to take data from many different sources and integrate it into common resources that can be used to inform decision making and offer close support for operation of modern utility T&D systems. Another challenge addressed by this project is interfacing with federated data resources.

Approach

In this project, EPRI will expand the ability to integrate data sets to enable informed decision making. This effort includes not only data acquired from PQ monitors, but also other data sets and federated data sets, including smart meters, reliability, maintenance, recloser and switchgear operations, lightning, and weather.
Impact

- Integrates data from multiple and federated resources, which is of great value to utilities
- Data integration enables analysis and decision making that can significantly improve operational efficiency

How to Apply Results

Power quality and T&D engineering, design, operations, and maintenance professionals can best apply the results of this research by assimilating them and capturing the added monitoring capability routinely being integrated into such non-monitoring components as smart meters, relays, meters, switches, reclosers, circuit breakers, and regulators. Such integrated devices are often referred to as intelligent electronic devices. The addition of federated data resources enables advanced diagnostic and analysis functions.

2012 Products

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<tbody>
<tr>
<td>Integration of Data from Multiple Sources:</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>This project integrates PQ and system data from multiple and federated sources to enable improved decision making.</td>
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</table>

P1.005 Advanced Applications for Monitoring Systems (062153)

Key Research Question

The EPRI PQ program has identified issues relating to PQ data and monitoring as fundamentally important to the success of electric utilities in the coming years. Power quality monitoring systems capture significant amounts of data that describe the performance of the power system and the condition of power system equipment. These data have traditionally been available only for historical analysis and reporting. However, advances in communications systems are making these data available in near real-time, and the integration of data from additional intelligent devices in the system is resulting in the ability to collect data from across the system. However, considerable barriers to realizing the benefits of these advances remain.

Approach

This research may increase the value of PQ monitoring systems through the development of advanced applications that can directly benefit system operation and maintenance. The applications build on existing monitoring system platforms to minimize the additional investment required to achieve these benefits. They also take advantage of the data available in PQ monitoring systems that can be used to assess equipment and system condition with appropriate analytical methods and system interfaces.

This project expands the value of PQ monitoring systems by using the data to develop important information about the health of the overall system and individual components. Alarms and reports can then be integrated with system maintenance procedures and operations to more efficiently resolve problems and improve equipment reliability. The net effect can be a dramatic improvement in system reliability and a reduction in maintenance and operation expenses—the most important justifications for monitoring systems in the future.

Work will focus on the following:
- New data visualization techniques
- Better methods to port useful PQ information to mobile devices (smart phones and tablets)
- New waveform compression and analysis techniques
- New fault analysis and incipient fault identification techniques
- Data mining for equipment and hardware problems
- New indices and performance modules
Impact

- Analysis techniques using PQ data offer tremendous economic value to utilities.

How to Apply Results

Power quality and T&D engineering, design, operations, and maintenance professionals can use the results of this research by assimilating them and applying them to existing and future PQ data resources.

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<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Advanced Applications for Monitoring Systems: This project expands the value of PQ monitoring systems by using the data to develop important information about the health of the overall system and individual components.</td>
<td>Software</td>
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P1.006 Monitoring System Development and Management (058586)

Key Research Question

Acquiring, storing, and analyzing PQ data are increasingly important but daunting tasks for modern electric utilities. The challenges of this process are many, including dealing with massive amounts of data in varying formats and quickly analyzing these data to acquire the knowledge necessary to make informed decisions that can save utilities many millions of dollars in expenses, troubleshooting, and reduced downtime.

Approach

This project provides for research on new, advanced features and capabilities for managing and analyzing PQ data and large PQ monitoring databases to enable quick and expert decision making. Specific focus areas are prioritized annually by funders.

Past focus areas have included the following:

- Fault location
- Data visualization
- Incipient fault and equipment failure analysis
- Voltage regulator performance module
- Fault protection and coordination assessment module
- Automated PQ and reliability reporting methods
- Transformer loading and lifetime assessment, including harmonics
- Arrester performance for transient events
- Capacitor switching data analysis

This project also provides for quality assurance evaluation of PQView®, a multi-component software system jointly owned by EPRI and Electrotek Concepts, for building and analyzing databases of power quality and energy measurements. Its components build measurement databases, write summary reports, compute power quality indices, view waveforms and rms samples, and trend steady-state quantities through workstations and web browsers. The software is being used by more than 50 utilities around the world.
Impact

- Utilities implementing preliminary EPRI-developed fault location algorithms have reduced average feeder downtime by approximately 1 hour per fault event.
- Other methodologies such as lightning and capacitor switching analysis have provided economic benefits for funders.

How to Apply Results

Power quality managers, engineers, and technicians receive new analysis capabilities for PQ data, which can be implemented in new or existing PQ analysis tools, including PQView. In addition, EPRI quality assurance testing of PQView gives funders access to software with additional validation.

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<tr>
<td>Monitoring System Development and Management: Advanced features and</td>
<td>12/31/12</td>
<td>Technical Update</td>
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<tr>
<td>capabilities for managing and analyzing PQ data and large power</td>
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<td>quality monitoring databases</td>
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<td>Quality Assurance Testing of PQView: EPRI quality assurance testing</td>
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<td>of PQView provides funders with access to software with additional</td>
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<td>validation.</td>
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PS1C Achieving Cost-Effective PQ Compatibility Between the Electrical System and Loads (062092)

Project Set Description

This project set will help EPRI members ensure electrical compatibility between the power system and the end-use customer's equipment. Power quality mitigation solutions significantly reduce electrical disturbances at the transmission, distribution, and end-use level by integrating advanced energy storage technologies with power electronics. The PQ Investigator is intended to capture EPRI expertise in end-use investigations in an expert system that may allow expedited and thorough investigation, diagnosis, and documentation of end-use PQ issues. This project set is also creating a library of end-use and DER models, which may allow assessment of the PQ impact of different and changing load configurations.

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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P1.007</td>
<td>System Compatibility Research</td>
<td>This research area characterizes compatibility issues between end-use</td>
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<td>equipment, power conditioning technologies, and power system performance.</td>
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<td>Activities include establishing evaluation criteria (for example, testing</td>
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<td>protocols), evaluating failure mechanisms, and identifying solutions. This</td>
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<td>research will acquire and distribute seminal compatibility information and</td>
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<td>knowledge.</td>
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<td>P1.008</td>
<td>Impact Assessment and Modeling of Grid-Connected Loads</td>
<td>This project creates a growing library of end-use and DER models, which</td>
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<td>and Power Supplies</td>
<td>may allow assessment of the PQ impact of different and changing load</td>
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<td>configurations. The load models developed in this project set are the best</td>
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<td>available and based on actual testing in EPRI's Knoxville laboratory.</td>
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<tr>
<td>P1.009</td>
<td>System Compatibility Resource Tools</td>
<td>Updated PQ Investigator Software: The PQ Investigator captures EPRI</td>
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<td>expertise in end-use investigations in an expert system that may allow</td>
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<td>expedited and thorough investigation, diagnosis, and documentation of end-use</td>
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<td>PQ issues.</td>
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P1.007 System Compatibility Research (062349)

Key Research Question

The EPRI PQ Program has identified several objectives related to understanding and improving the compatibility between electric power supply and end-use loads. A key barrier to achieving such successes is understanding the sensitivity of today’s end-use loads as well as new and emerging end-use loads.

Approach

This research area characterizes compatibility issues between end-use equipment, power conditioning technologies, and power system performance. Activities include establishing evaluation criteria (for example, testing protocols), evaluating failure mechanisms, and identifying solutions. This research will acquire and distribute seminal compatibility information and knowledge. As issues are studied and uncovered, solutions will be developed and applied by the other projects in this project set.

A second area of research will continue previous work with end users, vendors, and energy companies to establish PQ standards in the automotive, machine tool, and food-processing industries. Work has been ongoing in the food-processing area, where food-processing groups have already expressed an interest in adopting the SEMI F47 standard as a beginning step. In addition, work is progressing in the automotive industry, where standards are an important platform for their operations. One promising approach is to work toward the adoption of a ride-through recommendation, which is used by organizations such as IEEE. This approach allows the adoption of standards for many industries simultaneously rather than one industry at a time. These efforts can be coordinated with IEC to ensure international acceptance. Another approach is to press for the expansion of electrical codes to encompass performance issues. As more industries become willing to adopt the F47 curve, the end result could be a universal, one-size-fits-all type of standard.

A third research area involves developing a guidebook for designing equipment to avoid power quality problems.

Impact

- Improves customer satisfaction among key industrial and commercial customer categories
- Reduces the incidence of end-use customer process interruptions
- Enables more efficient and cost-effective development by end-use equipment manufacturers of equipment that meets PQ performance standards using the equipment design guidebook

How to Apply Results

Power quality and T&D engineering, design, operations, and maintenance professionals can best apply the results of this research by using the results of system compatibility testing and the associated guidelines to help end-use customers solve PQ-related issues and achieve higher productivity.

2012 Products

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<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
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<tr>
<td>Development and Promotion of PQ Compatibility Standards: This research area characterizes compatibility issues between end-use equipment, power conditioning technologies, and power system performance. Activities include establishing evaluation criteria (e.g., testing protocols), evaluating failure mechanisms, and identifying solutions. This research will acquire and distribute seminal compatibility information and knowledge.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>
P1.008 Impact Assessment and Modeling of Grid-Connected Loads and Power Supplies (062350)

Key Research Question
The behavior of new and changing end-use loads and grid-connected power supplies is beginning to affect grids around the world. Utilities need resources to test and evaluate these technologies so that their impact today and in the future can be assessed and managed.

Approach
This project creates a growing library of end-use and DER models, which may allow the assessment of the PQ impact of different and changing load configurations. The load models developed in this project set are the best available and based on actual testing in EPRI's Knoxville laboratory.

Impact
- Tests and evaluates technologies so that their PQ impact today and in the future can be assessed and managed
- Creates a growing library of end-use and DER models, which may allow the assessment of the PQ impact of different and changing load configurations
- Applies load models in the Grid-IQ Framework for the prediction of future grid PQ levels, including harmonics

How to Apply Results
Power quality and T&D engineering, design, operations, and maintenance professionals can best apply the results of this research by using them to better understand the PQ impact of loads today and in the future.

2012 Products

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<tr>
<td>Impact Assessment and Modeling of Grid-Connected Loads and Power Supplies: This project creates a growing library of end-use and DER models which may allow assessment of the PQ impact of different and changing load configurations. The load models developed in this project set are the best available and based on actual testing in EPRI's Knoxville laboratory.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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P1.009 System Compatibility Resource Tools (048281)

Key Research Question
Project members will benefit from expert systems that help them show customers the causes of and solutions for the PQ problems they are facing. This challenge is particularly acute in the industrial sector, which consists of a diverse range of processes, equipment, and power quality issues.

Approach
EPRI's system compatibility resource provides a wide range of support to detect, mitigate, and prevent end-user PQ issues. The PQ Investigator is an expert system for investigating and solving end-user PQ issues. It is based on 500 person-years and hundreds of facility audits worth of experience.
Impact

- Captures EPRI expertise in end-use investigations in the PQ Investigator expert system to conduct expedited and thorough investigation, diagnosis, and documentation of end-use PQ issues
- Helps members train new PQ engineers, refresh experienced representatives, and enhance the credibility of all employees
- Improves the relationship between the customer and energy company by demonstrating that the company has invested the time and resources needed to research these problems in depth

How to Apply Results

Power quality and T&D engineering, design, operations, and maintenance professionals can best use the results of this research by assimilating them and applying the Industrial Design Guide with industrial customers to show the causes of and solutions for PQ-related issues they are facing.

2012 Products

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<tr>
<td><strong>Updated PQ Investigator Software</strong>: The PQ Investigator captures EPRI expertise in end-use investigations in an expert system that may allow expedited and thorough investigation, diagnosis, and documentation of end-use PQ issues.</td>
<td>12/31/12</td>
<td>Software</td>
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Supplemental Projects

PQ Knowledge Development and Transfer (Formerly PS1D) (072185)

Background, Objectives, and New Learnings

Management of power quality issues has never been an easy task, but it has grown even more difficult with deregulation, reregulation, increasingly scarce technical and strategic tools, and a conspicuous lack of unbiased resources for information, collaboration, advice, and problem solving. Moreover, with the ever-increasing use of sensitive digital and electronic equipment in today’s economy, end-use customers are not only demanding higher quality power, but also are calling upon utilities to help resolve PQ problems within customer facilities.

Project Approach and Summary

This project seeks to find new information that electric service providers can use to cost-effectively meet customer and internal demands. It utilizes EPRI’s extensive collaborative research in power quality to provide a wealth of easy-to-use, informative PQ resources for utility staff as well as materials they can use to inform end-use customers. It offers a comprehensive collection of technical and informational publications and products, educational forums, technical support, and web-based services. In addition, the project provides information and resource tools needed to help minimize economic losses and more effectively compete in today’s marketplace. It also serves to build a foundation of knowledge regarding the latest PQ products and expert insights into power quality.

Benefits

This program offers a number of benefits for members. Some examples include:

- Provides extremely high value to PQ managers, engineers, and technicians, using individual participants’ contributions by at least a 20-to-1 ratio
- Provides the ability to access EPRI experts and network with industry peers both inside and outside the utility industry~
Distribution and Transmission Power Quality Benchmarking (TPQ/DPQIII) (069592)

Background, Objectives, and New Learnings

Power quality is affected by the load as well as power delivery components and operations methods. Both load composition and the power deliver system are changing and have affected the levels of various PQ phenomena. Previous benchmarking studies are reaching an age at which they may not serve as a realistic benchmark for comparison. This study aims to update existing benchmarks to include changes in load composition affecting the grid, including a shift to plug-in loads and an increase in the number of power supplies as well as peak shifting equipment and emerging efficient technologies. A second focus will be on impacts caused by changing power delivery system designs and compensation that have affected the PQ levels in both transmission and distribution. There is a need to re-create the definition of acceptable levels of power quality for key phenomena—including harmonics, flicker, and voltage sags—that can be applied at the T&D level. IEEE has a working group with the task of defining typical and expected PQ levels for the electric supply system. This project may help the task force by providing a wealth of factual information as a basis for recommendations.

Project Approach and Summary

This project will gather T&D system PQ monitoring data sets from a wide range of utilities and systems and perform a meta-analysis of the data and other PQ studies, including previous EPRI power quality surveys and monitoring efforts.

Benefits

The information learned from this project may be used by a variety of utility functions. Management may use it to set performance goals and engineer for better understanding of requirements. Utilities may use the result of the benchmarking efforts to discuss the expectation and economic impact of PQ levels. The expected results may also provide a factual baseline for the benchmarking of power delivery system performance required by regulatory bodies and may help in understanding the following:

- Utility-specific performance for T&D power quality and how these standards compare with a national baseline
- Power quality trends for T&D created by power electronics and emerging efficient technologies
- Power quality trends caused by increased distributed and renewable generation technologies

Using data industry standards will enable the integration of data from many diverse sources into a common database for analysis. This project is ideal for collaborative research, allowing the collection of significantly more data and reaching statistically representative samples for the load and delivery system. This benchmark is expected to offer T&D system managers a way to compare system performance against a national empirical benchmark.

Understanding the power quality benchmark performance may benefit the public by helping utilities to optimize resources in achieving expected and levels.

IEEE has a working group that is defining typical and expected PQ levels for the electric supply system. This project may help the task force by providing a wealth of factual information as a basis for recommendations.
Smart Electromagnetic Interference Problem Solver and Detection System (071986)

Background, Objectives, and New Learnings

Failing equipment may cause interference problems when generating detectable emissions with unique signatures. In many cases, a power or signal filter or a shield begins failing with no way to detect the failure. Failure mechanisms progress until complete equipment shutdown occurs, resulting in plant shutdown and an electromagnetic interference (EMI) investigation. EMI investigators consistently point out that prior detection of internal failures would have avoided a shutdown.

Automated emissions measurement techniques and systems are gaining interest in power and electromagnetic compatibility (EMC) communities. Standard EMC measurement systems are too large to use in cramped environments in consumer and power plant facilities. This research will seek to develop a portable lightweight EMI detection system and problem solver to detect radiated and conducted emissions from 10 kHz to 10 GHz, identify emissions sources, and determine their distance to industry limits. Research will develop algorithms to determine which emissions sources are causing EMI problems. A miniature walk-around device with these capabilities could offer utility engineers an efficient and intelligent way to identify the cause and location of EMI problems.

This project explores new technologies and methods to identify sources of electromagnetic interference and may enable mitigation of these phenomena before they lead to malfunction of electronic equipment.

Project Approach and Summary

Automated and programmable emissions measurement systems used in previous EPRI research have demonstrated that emissions measurement equipment can be programmed to make long-term emissions recordings and perform basic analyses on recorded emissions.

Computing power, functionality, and data handling capabilities of high-speed platforms used in spectrum analyzers along with broadband antennas capable of kHz-to-GHz detection will be evaluated for use in the new detection system.

Smart algorithms that can detect problem-causing emissions leading to an EMI problem and identify their sources, proximity to industry standardized limits, and rate of occurrence will be developed. Participating utilities will be asked to identify up to three utility or customer sites where the new system can be field tested. The on-board tools to analyze emissions and determine the likelihood of an EMI problem will also be tested in the laboratory and at the field sites.

Benefits

The public may benefit from the results of this project by enabling identification of the root cause of equipment malfunction, and implementation of corrective action before actual malfunction which may lead to power outages or lower power quality.

- Offering the utility a technology that can identify a source’s location will help avoid equipment failures, improve equipment reliability, enhance occupational safety, and lower cost.
- Leaky shielded cables and equipment usually go undetected until an EMI problem occurs. Avoiding one EMI problem may save utilities and their consumers the cost of equipment downtime and repairs, lost productivity, and other potential consequential damages. Finding root causes of EMI problems may help to quickly repair the problems and mitigate the associated risks.
- Detecting an ongoing but unknown emissions source will help identify potential safety problems when radio-frequency energy is used in an industrial process.
Energy Storage - Program 94

Program Overview

Program Description

As utilities integrate greater amounts of variable renewable resources into their systems they will require finding solutions to provide flexibility for the inherent variability of wind and solar energy resources. Energy storage technologies offer a viable source of flexibility. In addition storage may also provide a temporary solution to overcome regional and local capacity shortages, providing relief to localized transmission and distribution congestion.

Advances in technology and expansion in production capacity have reduced the price of some energy storage technologies, bringing them to the verge of cost-effectiveness. Their cost-benefit relationship, at best, is still marginal and requires taking full advantage of potential benefit streams to approach becoming cost effective. But the applications that contribute to the value of storage solutions have various and different requirements, from meeting certain ramp rates, storage capacity, and/or round trip efficiency, and these requirements have not yet been systematically developed.

New storage technologies are rapidly maturing and are beginning to become practical in grid applications. However, there are still significant challenges to overcome:

- understanding the performance characteristics, cost and expected service life time of various storage technologies
- defining the requirements specification for the various applications to facilitate the transformation of custom storage implementations to applications of predefined storage products;
- understanding the possible impact on transmission and distribution system planning as well as construction and operations;
- assessing the various uses of storage, including the performance requirements, cost breakeven points and valuation;
- understanding the policy impacts, including market policy and/or regulation decision, on the adoption and cost effectiveness of storage applications.
- understanding the environmental impact of storage applications
- assessing the maturity of various storage technologies for grid applications.

Research projects that address these challenges can help to move this technology forward.

Research Value

EPRI research focuses on enabling grid-ready energy storage products for utility applications.

The EPRI collaborative research environment enables engagement with utilities, storage vendors and other stakeholders to test and evaluate new technologies and products, define functional requirements for energy storage systems, develop tools and methodologies to analyze the effects of storage on the power delivery network and optimize their use, and create approaches that assess the business cases for storage in various applications and regions.

Through this program utilities, government bodies, storage developers and vendors, electricity end users, and other stakeholders will be better informed about the opportunities and challenges facing electric energy storage technologies and products deployed on the grid.
Approach
This EPRI research will be shared with members of the program in a number of formats, and is expected to include:

- Strategic intelligence and specific technology assessments of energy storage and related distributed energy resource options
- Industry white papers to inform stakeholders on maturity of various storage technologies and potential of grid related applications
- Develop functional requirements specifications for storage systems providing ancillary services and mitigating variability of renewable resources, mitigate local transmission and distribution congestion allowing the deferring upgrading the local infrastructure, and neighborhood energy storage systems for end-use peak load shifting and outage reduction.
- Comprehensive energy storage cost and performance database for all energy storage options by application
- Monitoring and providing case summaries of on-going energy storage demonstrations
- Test reports providing data on the operating envelope, performance, and durability of emerging energy storage systems
- Case studies to define storage operational requirements; suitable locations and scale as well as duration requirements of storage solutions for maximizing the expected benefits

Accomplishments
In the past, the Energy Storage program has delivered valuable information that has helped its members and the industry in numerous ways. Some examples include:

- EPRI published a comprehensive analysis (Product ID 1020676) of energy storage applications and technology options that also assesses the potential benefits and markets for energy storage in the United States. The analysis looks at 10 energy storage applications that EPRI considers would serve the bulk of the energy storage market and includes applications to support wholesale energy services and renewable integration.
- Energy Storage Technology and Application Cost and Performance Database-2010 (1020071). This report presents updated data on the cost, performance, and capabilities of energy storage systems for various applications in an Excel workbook database. The goal was to develop objective and consistent installed costs and operational and maintenance costs for a set of selected energy storage systems in the identified applications.
- Lithium-ion Energy Storage Market Opportunities (1020074). This report presents cost/benefit analysis for Li-ion based energy storage systems for utility and customer-side of the meter stationary applications. This report is intended to inform utilities of the near-term opportunities for Li-ion energy storage and provide guidance for focused testing and field demonstration to reduce technical and business uncertainty and enable grid-ready energy storage systems by 2015.
- Impacts of Energy Storage Systems in Addressing Regional Wind Penetration: Case Studies in NYISO and ERCOT (1020082). This project evaluated the Independent System Operator (ISO) system benefits of bulk and distributed energy storage system deployment under regional specific wind penetration scenarios in the PJM, NYISO, and ERCOT markets to assess the role and value of energy storage options and address key research questions on the role and value of wind to support wind integration.

Current Year Activities
In the coming year, this research program expects to accomplish these objectives:

- Updated Energy Storage Cost Database
- Energy Storage Benefit and Cost Analysis tool
- Energy Storage System Test and Evaluations
Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P94.001</td>
<td>Strategic Intelligence and Technology Assessments of Energy Storage and Distributed Generation</td>
<td>This project provides analysis and strategic information on energy storage and distributed energy resource systems through an online technology assessment database, annual technology assessments, and strategic intelligence reports. Analysis is undertaken to understand the impacts of energy storage systems, including their costs, benefits, potential value. It also includes assessments and evaluations of various technologies. Some of the information may be published in white papers to inform the public, including regulators and other stakeholders.</td>
</tr>
<tr>
<td>P94.002</td>
<td>Distributed Energy Storage Options for Power Delivery and End Use</td>
<td>This project provides information and guidelines for using distributed energy storage and distributed generation systems for power delivery and end-user applications such as infrastructure investment deferral and peak management, including shifting. To achieve this, the project conducts analyses, performs rigorous laboratory testing and field demonstrations, and prepares informative case studies of current and emerging battery energy storage systems.</td>
</tr>
<tr>
<td>P94.003</td>
<td>Bulk Power Energy Storage Solutions</td>
<td>This project provides information and guidelines for using bulk energy storage to shift low-cost, off-peak energy to high-value, on-peak energy and provide ancillary services including for integration of bulk variable generation. It includes R&amp;D on technologies such as low-fuel CAES systems, pumped hydro, and emerging large flow battery systems. The project also conducts analysis and encourages consistent modeling of energy storage with commercial tools.</td>
</tr>
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</table>

P94.001 Strategic Intelligence and Technology Assessments of Energy Storage and Distributed Generation (051547)

Key Research Question

Utilities and other stakeholders require strategic, factual and empirical information on current and emerging energy storage and distributed energy resource technologies and products, which could bring new opportunities for utility operations and may reduce carbon emissions.

Such information includes technical characteristics, performance and cost information, and trends in energy storage and distributed generation options. Analysis is needed to improve the understanding and assess the costs and benefits of energy storage and of distributed resources in a smart grid, including the associated impacts of greenhouse gas emissions as well as resource planning.

Approach

This project provides analysis and strategic planning information on energy storage systems through technology assessment database, annual in-depth technology assessments, and strategic intelligence reports. The project
performs "technology watch", tracks, monitors and summarizes all on-going energy storage demonstrations. The
program also "tracks" developments and trends in distributed generation options like fuel cells. In addition the
project also monitors the applications of small to large energy storage options for frequency regulation and end-
use peak load-shifting in transmission and distribution,

Analysis is undertaken to assess the technology, operational values, costs and benefits, and impacts of energy
storage systems including distributed and bulk energy storage systems as well as novel flow battery
technologies. This includes benchmarking of energy storage and advanced distributed generation technologies. The results are maintained in a comprehensive energy storage system cost database.

In 2012, the program will focus on uncertainty and related risks, operation and maintenance costs, and
estimation of cost per delivered kilowatt-hour over the project life.

The project enhances an analytic tool for electric storage business case assessments by including additional
applications of storage, adding functionality and releasing it as a beta software version. As a second activity, the
project will apply methods developed in EPRI's Smart Grid Program to estimate the value, benefits, costs, and
greenhouse-gas impacts of implementing a distributed energy resource portfolio within a utility planning
framework.

This project monitors and reports summary information for all energy storage demonstrations projects under
way in the United States, as well as a select number of international projects and demonstrations.

Selected research results and findings will be made publicly available, at no cost, as white papers or technical
briefs to better inform the public, policy makers and other stakeholders about the role, requirements and value of
electric energy storage systems to the electric industry.

Impact
Participants in this project could be affected in a number of ways including:

- Having access to timely information on trends and developments in energy storage and distributed
generation.
- Acquiring strategic intelligence on emerging technologies that can affect utility business operations.
- Gaining insight into the carbon reduction impacts of energy storage and distributed generation systems.
- Receiving objective information to support strategic corporate planning and answer regulatory inquiries.
- Having access to EPRI's energy storage cost / system database, as well as assessments to support
corporate strategy and decisions to invest in distributed generation and energy storage initiatives.
- Learning how to quantify the value of a distributed resource portfolio for utility business operations.
- Getting information to support win-win policies for deploying energy storage systems.

How to Apply Results
Research findings can be used by corporate and resource planners as part of their strategic planning function,
and could help them anticipate technology trends and apply solutions to business issues. Distribution system
designers of smart grids may incorporate research findings and results into future grid expansion assessments.
Results could also be used by regulatory policy and regulatory affairs managers to respond to state public
commission inquiries related to distributed generation and energy storage costs, benefits or market integration,
as well as inquiries related to greenhouse gas emissions and impacts of decentralized generation. Corporate
strategic planners can use EPRI research findings and products to:

- Respond to senior management inquiries
- Evaluate the technology and investment risks of distributed generation and energy storage initiatives
- Inform senior management on technologies that could affect or improve business operations
- Inform policy makers.
2012 Products

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<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tr>
<td><strong>Strategic Intelligence Reports:</strong> Strategic intelligence reports provide objective information on current and emerging distributed generation and energy storage technologies that could influence or support utility business operations and reduce carbon emissions. Up to 5 reports are produced, with a feature story and summaries of the latest information on the cost, performance, and trends of distributed generation and energy storage options that are available from credible sources in the literature.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Cost and Technical Capabilities of Energy Storage Systems:</strong> The product will provide updated cost, performance and technical information on energy storage systems for applications in the electric enterprise, including technical data sheets, reference applications and current and forecasted cost estimates for a large set of storage solutions including: CAES, NaS, NaNiCl2, various flow batteries, lead acid, advanced lead acid, Li-ion, and emerging technologies.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Industry White Papers:</strong> This product will be a publicly available industry white paper or industry technical briefs to better communicate the role, requirements and value of electric energy storage systems to the electric enterprise.</td>
<td>12/31/12</td>
<td>Peer Literature</td>
</tr>
<tr>
<td><strong>Analytic tool to Assess the Value and Support the Business Case of Energy Storage and Distributed Resources:</strong> This product will provide the results of analysis and an analytic tool to support utility business case evaluations of investments in energy storage and distributed energy resources, describing new applications and functionality options, a total resource recovery cost (TRC) test and life-cycle analysis methodology, and results from analyses to estimate the value, benefits, costs, and greenhouse-gas impacts of implementing a distributed energy resource portfolio within a utility planning framework.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td><strong>Monitoring and Reporting on Energy Storage Demonstrations:</strong> This product provides summary information on all DOE and utility-sponsored national and international energy storage demonstrations via a database and case studies.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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P94.002 Distributed Energy Storage Options for Power Delivery and End Use (065556)

**Key Research Question**

Aging grid infrastructure, the challenge of installing new lines, and requirements for higher reliability are prompting many utilities to consider energy storage and distributed generation options for capital deferral, grid support, distribution planning, and end-user energy management. This requires the availability of proven, grid-ready distributed electric energy storage options for use in transmission and distribution applications, along with the methodologies and tools required to integrate those products to the grid.

To deploy and utilize these assets in substations, along the feeder, and beyond the meter, utilities need empirical information on costs, performance, operational characteristics, reliability, risks, and durability. Research is required to better understand grid integration solutions and tools including energy storage system capabilities, such as performance; efficiency and cycling capability.

This project tests and validates energy storage capabilities and advances grid integration tools via case studies and tool development. Research is undertaken to understand the performance and technical readiness of energy storage technologies to provide desirable utility modes of operation under varying conditions as well as the effects of storage on the grid in terms of stability, control and reliability; and understanding what must be
done in terms of T&D system planning, construction, and operation to ensure the physical connection of storage solutions is effective.

Approach

The project will provide information and guidelines for using energy storage and distributed generation systems for temporarily deferring investments in local grid infrastructure by shifting the load from peak to off-peak. The project also assesses storage solutions for meeting end-user load management and peak load-shifting needs and compares the findings with other options.

The project develops detailed application-specific requirement specifications for grid support storage systems located in substations and at the end-of-line, which are co-located with pad-mounted transformers. This includes compatibility requirements with utility operations control systems. This effort may lead to standardized DESS systems in the 2 kW to 100 kW scale, which would greatly accelerate their readiness for deployment.

The project will expand the storage-grid integration efforts started in 2011. R&D activities include modeling to understand the effects of storage on the grid in terms of voltage impact, control and using OpenDSS to better understand storage operational requirements; identify suitable locations and scale for connecting storage.

Impact

Participants may be affected in a number of ways including:

- Obtaining demonstrated capability to use distributed energy storage for grid support
- Procuring, installing, operating, or contracting for energy storage systems in a safe and reliable manner by employing guidelines and best practices
- Understanding risks based on validated test data for performance, costs, and operational issues related to energy storage and selective emerging distributed energy resource options
- Incorporating the use of distributed energy storage options into T&D planning
- Understanding options for deferring T&D capital investments by applying storage solutions for peak management
- Making more informed purchase and deployment decisions for energy storage systems.

How to Apply Results

Research findings may be used by distribution planners to develop grid operational solutions, and by engineers and planners when developing a smart grid implementation. Distribution system designers of smart grids can incorporate research findings and results into future grid expansion plans. Results from case studies and evaluations can be used to assess the risk and value of energy storage to utility business operations. Results can also be used to develop new energy management and demand-response solutions for end-use customers.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Substation and DESS Product Technical Specifications: This product will include the results of activities towards detailed application specific technical specifications for substation grid support and end-of-line transformer DESS systems.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Energy Storage Testing and Validation of Utility and End-User DESS: This report will describe the results of field testing and demonstration efforts of Distributed Energy Storage Systems (DESS) started in 2011. The DESS systems will include standardized energy storage products in the 2 kW to 100 kW range, deployed at program member facilities.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
### MW scale Energy Storage Systems for Substation and Grid Support

**Product Title & Description**

This product will describe the results of field testing and evaluation of megawatt-scale energy storage systems for substation and grid support.

**Planned Completion Date:** 12/31/12

**Product Type:** Technical Update

### Energy Storage Grid Integration efforts to ensure grid ready systems by 2015

**Product Title & Description**

This product will include results from research activities to understand the effects of storage on the grid in terms of stability, control and reliability. Case studies are undertaken using tools like OpenDSS to better define storage operational requirements, best locations, scale and energy duration of storage solutions for maximum impact.

**Planned Completion Date:** 12/31/12

**Product Type:** Technical Update

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**P94.003 Bulk Power Energy Storage Solutions (065557)**

**Key Research Question**

The electric enterprise requires cost-effective and reliable bulk energy storage to help balance and optimize supply and demand of bulk power resources, including nuclear, fossil, and renewable resources. This may include enhancing transmission system effectiveness and shifting low-cost, off-peak generated energy to provide on-peak, high-value energy.

In addition, state renewable portfolio standards (RPS) are causing a high penetration rate of variable renewable resources. Bulk power storage may be one option to help utilities manage the variability of renewable resources. This project examines the functional requirements and storage technology capabilities for mitigating the effects of variability of renewable generation. It also analyzes the possible impact of bulk energy storage on long term planning.

Presently, several technologies are at a maturity level that may help meet the requirements, including compressed air energy storage (CAES) and pumped hydro. Pumped hydro needs to be re-examined and assessed for its ability to provide cost-effective bulk storage. Selected battery technologies may also be approaching a maturity level such that they could be considered for these types of applications. New trends and developments in large flow-battery systems may require reconsideration of vanadium, Zn/Br, and Zn/Cl redox cycle technologies for use in large bulk storage applications.

**Approach**

This project provides information and specific solutions based on advanced CAES and large battery storage systems to improve the value of large-scale variable renewable generation. It also conducts regional impact R&D to assess grid and environment impacts of storage.

This work will include determination of functional specifications needed, performance under alternative transient conditions (e.g., part load duty, frequency regulation duty, up-ramp duty, down ramp duty), estimated capital and maintenance costs for SCR for alternative duty cycles, performance curves for alternative duty cycles, and capital and maintenance cost documentation.

Functional requirements for advanced control system logic will also be developed to enable a CAES plant to cost-effectively dispatch or participate in multiple energy and ancillary service markets.

Other work to be prioritized by funders may include better estimation of geologic opportunities and locations near wind penetration regions; practices for site selection and permitting of CAES systems; EPRI will also track A-CAES developments and lead R&D in thermal storage assessments and development with use of Technology Innovation funding.
The project will also define and benchmark non-CAES bulk storage options including flow batteries, NaNiCl2, and Na-ion storage systems which may include a 50 MW Battery storage system. As storage systems reach a higher level of readiness for deployment, the program will evaluate and compare existing economic and cost benefit analysis tools that support both bulk and distributed energy storage options.

EPRI plans to collaborate with storage research stakeholders such as Sandia and NREL and other EPRI internal resources to conduct a transparent benchmarking study.

Impact
Participants may be affected by this project in a number of ways including:

- Increasing the market penetration of variable wind power
- Improving cost-effectiveness and reducing the industry’s greenhouse gas emissions profile
- Learning about assessments and timelines for advanced bulk energy storage systems
- Improving their utilization and operation of transmission assets
- Improving their understanding of the system-wide benefits of CAES and other bulk energy storage
- Improving their use of fossil assets by reducing thermal generator ramping and lowering greenhouse gas emissions when using storage for ancillary services and load following.

How to Apply Results
Research findings could be used by corporate strategic planners, resource planners, and system planners as well as utility design engineering staff. Planners and operators of bulk power generators may use the results to plan new projects as well as increase the utilization of existing base load or intermediate-duty generation assets. Independent system operators (ISOs) can incorporate project findings into their planning and market development activities.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Reference CAES Designs and ISO Integration Requirements: This product will include an updated CAES system reference design and functional requirements for the use of CAES in a variety of market applications.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Reference Bulk Battery Designs and ISO Integration: This product will present the results of the definition and benchmarking of non-CAES bulk storage options, as well as the results of implementation of a 50 MW bulk storage system used cooperatively by an IPP and a T&amp;D utility.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Regional Analysis of Energy Storage in meeting Intermittent Renewable Generation and Grid Impacts: This product will deliver the results of the evaluation of the potential for energy storage systems to help with the integration of large amounts of renewable resources in specific ISO scenarios, as well as a comparison benchmarking of several economic cost-benefit tools to evaluate bulk storage plants.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Demonstration of a 36 MW Dynamic Power Resource at a 150 MW Wind Farm: This product will report data and analysis from a 36 MW / 30 MWh battery system provided by Xtreme Power installed at a 150 MW wind farm in the Texas ERCOT market, including impacts on wind integration and the dispatch practices.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
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Supplemental Projects

Lithium Ion Demonstration (072067)

Background, Objectives, and New Learnings

Global scale up of Li-ion batteries for electric transportation could enable cost effective storage systems for certain grid support use cases. The unique qualities of Li-ion technology and the overlapping objectives of low-cost, long-life, and high energy density shared by distributed energy storage (DES) and plug-in electric vehicle (PEV) markets may create an opportunity for cost-effective grid systems by 2015. The potential for rapid PEV battery production scale-up due to the release of mass produced plug-in vehicles in 2011 highlights the promise to material technology and cost improvements.

The key research objectives of the demonstration are to:

- Assess viability of and establish track record for plug-in electric vehicle (PEV) battery technology to be used in grid energy storage systems;
- Test and validate performance against technical specifications and operational uses;
- Assess technical performance and economic benefits of energy storage systems with multiple sites and operating modes;
- Assess capability to “stack” multiple operating benefits in a single energy storage system.

Project Approach and Summary

In Phase II A, this project will procure (buy or lease) energy storage systems based on the technical specification developed in 2011. Host utilities will operate the systems and EPRI will provide site testing guidance, monitoring, analysis and reporting. The initial demonstration period will last approximately 2 years.

The following is a high level summary of tasks:

- Manage procurement, risk management, & support logistics for energy storage systems
- Provide timely monitoring data & analysis of demonstration system performance and summary of lessons learned
- Analysis of system technical performance and impact on utility grid operations and economics
- Technology transfer via quarterly memoranda, annual reports, and utility / supplier workshops

Benefits

Public benefits of this demonstration are improved technical understanding of Li-ion energy storage technology, which may increase grid reliability, enable increased penetration of intermittent renewable energy resources, manage peak demand, and reduce end-user electricity prices.

Funder benefits include understanding the value and technical capability of a first-of-a-kind energy storage grid asset with the potential “stack” benefits by addressing several grid issues; and, understanding the Li-ion technology platform’s potential to serve both utility and plug-in electric vehicle applications.
IntelliGrid - Program 161

Program Overview

Program Description
Utilities are increasingly deploying advanced monitoring, communications, computing, and information technologies to support smart grid applications such as wide area monitoring and control, integration of bulk or distributed renewable generation, distribution automation, and demand response. Companies face significant challenges when deploying these technologies, including:

- Selecting technologies that best meet current and future business needs and regulatory requirements, while minimizing the risk of early obsolescence and vendor lock-in
- Creating an overall architecture that integrates the many intelligent devices, communications networks, and enterprise systems to utilize resources and provide information to all users
- Managing the tremendous amount of data that is generated by the smart grid, converting data into actionable information and effectively present the information to the people who need to take action
- Managing a growing network of intelligent devices that have different capabilities and that use different protocols and data formats in a way that optimizes performance
- Ensuring that the workforce has the skills necessary to design, operate, and maintain equipment and systems that use new technologies

The IntelliGrid Program will address these challenges by:

- Tracking federal government and regulatory activities relating to standards, cyber security, and communications and interpreting the impact that these actions will have on the utility industry
- Promoting interoperable systems by contributing to the development of key smart grid standards, assessing emerging standards, conducting interoperability tests of products that implement key standards, and providing information to utilities on how to implement standards
- Defining requirements for utility communications networks and assesses key communications technologies
- Facilitating smart grid demonstration projects around the world to better understand and advance the use of distributed energy resources in smart grids

Research Value
With the knowledge acquired through this research program, members will have access to information that can help them with:

- Assistance in how to best deploy monitoring, communications, computing, and information technology to address unique business and regulatory drivers, addressing questions as to which products and technologies to use, when to implement solutions, how to integrate new and existing systems, and how to manage systems
- Development and support of standards-based approaches for achieving interoperability of technologies that make up a smart grid
- An understanding of the impact that federal government and regulatory activities relating to standards and communications will have on the utility industry
- Utility implementation approaches and results for smart grid technologies and systems
- Roadmaps for implementing a smart grid
- An understanding of communications and information system architecture requirements to support a smart grid
Approach

EPRI research in the IntelliGrid Program will yield a variety of data and knowledge that will be beneficial to members of the program. This information will come in a number of forms and is expected to include:

- White papers on utility experience with adopting standards and migrating from one standard to another
- Reports on lessons learned and best practices when deploying applications
- Reports on interoperability testing of vendor products to standards such as the Common Information Model (CIM) and Smart Energy Profile 2.0 (SEP 2.0)
- Contributions of technical reports to standards development organizations and industry groups

Accomplishments

In the past, the IntelliGrid Program has delivered valuable information that has helped its members and the industry in numerous ways. Some examples include:

- *Concepts to Enable Advancement of Distributed Energy Resources* (1020432) highlights a shift in approach from using "command and control" to "inform and motivate," which would allow the customer and the grid to interoperate with full transparent, extensible, and scalable interoperability.
- *Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects* (1020342), completed with DOE, presents a framework for estimating the benefits and costs of smart grid demonstration projects and a step-by-step approach for making these estimates.
- *EPRI Smart Grid Demonstration Initiative: Two Year Update* (1021497) describes the progress in EPRI's demonstration project of developing a foundation of tools and references, while performing research to support the advancement of distributed energy resources in large-scale demonstrations.
- *Accuracy of Digital Electricity Meters* (1020908) provides a historical perspective of electromechanical meters and highlights the transition to solid-state models and the factors that influence the perceptions of them in the market today.
- Smart Grid Interim Interoperability Roadmap Report: The National Institute of Standards and Technology (NIST) awarded EPRI a contract to engage smart grid stakeholders and develop a draft interim standards roadmap, which NIST has used as a starting point in developing an NIST interim roadmap for smart grid interoperability standards. EPRI technical experts compiled and distilled stakeholder inputs, including technical contributions made at two EPRI-facilitated two-day public workshops.

Current Year Activities

Research results will address near-term needs as well as make contributions that will advance the industry toward open, standards-based systems and devices that are interoperable and secure. Specific objectives include:

- Migration path for International Electrotechnical Commission (IEC) 61850 implementation and coordination with CIM, Distributed Network Protocol (DNP), and MultiSpeak (a registered trademark of the National Rural Electric Cooperative Association) standards
- Evaluation of open standards and testing of interoperability for end-load management, including SEP 2.0
- Development of an open, standards-based platform for disseminating and visualizing operational data to mobile devices
- Tracking and analysis of smart grid regulation and technology trends
- CIM training and interoperability tests for transmission, distribution, and advanced metering
- Guidelines for deploying communications infrastructure for transmission operations, advanced distribution automation, demand response, and energy efficiency
- Regular reports on laboratory testing of technologies and products

Estimated 2012 Program Funding

$3.9M

Program Manager

Donald Von Dollen, 650-855-2210, dvondoll@epri.com
Summary of Projects

PS161A IntelliGrid Technology Transfer and Industry Coordination (063528)

Project Set Description

This project set provides the overall industry coordination and high-level technology transfer activities related to continued development of the utility infrastructure to support smart grids. It supports users of the IntelliGrid architecture methods and introduces potential users to the benefits of migrating toward an intelligent grid. Every activity is designed to enhance access to research results so that both continuing and new funders of the IntelliGrid Program will find value. IntelliGrid Program members include utilities, vendors, public organizations, and other research organizations. One of the important objectives of this project set is to enhance coordination across all the different research organizations and industry organizations (for example, the U.S. Department of Energy [DOE], the Institute of Electrical and Electronics Engineers [IEEE] Intelligent Systems Coordinating Committee, and European smart grid efforts) working on the development and definition of future system architectures and integration needs.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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| P161.001       | IntelliGrid Technology Transfer and Industry Coordination | The project provides coordination across the industry. Important efforts include:  
- Tracking activities relating to the smart grid at NIST, FERC, and the FCC and providing an analysis of these activities  
- Tracking communications technology developments  
- Organizing a smart grid roadmap workshop for sharing information related to roadmaps for smart grid implementation  
- Conducting analytical studies on topics that will influence the deployment of smart grids  
- Reporting on industry-wide smart grid activities via an update to previous reports  
- Coordinating with international smart grid initiatives and reporting lessons learned to members |

P161.001 IntelliGrid Technology Transfer and Industry Coordination (065585)

Key Research Question

Utilities are increasingly deploying advanced monitoring, communications, computing, and information technologies to support smart grid applications such as wide area monitoring and control, integration of bulk or distributed renewable generation, distribution automation, and demand response. There are activities underway at the National Institute of Standards and Technology (NIST), the Federal Energy Regulatory Commission (FERC), the Federal Communications Commission (FCC), and various standards bodies that could have an impact on these deployments. Communications technology is advancing rapidly. These advances will impact current and future smart grid deployments.

Utilities need to be aware of industry, regulatory, and technology trends and the impact that they may have on current and future smart grid deployments.

The objectives of this project are to:
- Track industry and government activities, and provide an analysis on how these activities could impact utilities and how they can best prepare.
- Track communications technology advances and their impact on utility applications.
- Make contributions of EPRI results to relevant industry and government efforts, such as the NIST Smart Grid Interoperability Panel (SGIP), Open SG, and standards development activities.
- Provide a forum for utilities that are developing or implementing smart grid roadmaps to share experiences and lessons learned.
- Facilitate technology transfer of EPRI-developed R&D through webcasts and white papers.

**Approach**

This project provides coordination across the industry for smart grid technology implementation and deployment. Numerous smart grid efforts are under way at individual utilities, DOE, various standards organizations, and internationally. This project tracks relevant activities at NIST, FERC, FCC, and standards bodies to provide funders with information and analysis. The project also provides coordination across all these efforts so that members can take advantage of important developments and lessons learned across the entire industry. Coordination is achieved through sharing of use cases, member forums, webcasts, newsletters, and workshops.

**Impact**

Many utilities do not have the resources to actively participate in industry activities. This project will provide tracking information on those activities. The analysis of the impact that these activities will have on utilities will help utilities in planning their smart grid deployments and will help minimize the risk when selecting technologies. The smart grid roadmap interest group and workshop will provide lessons learned and experiences from a large group of utilities.

**How to Apply Results**

Utility executives responsible for “grid of the future” planning, information technology (IT) architects designing the infrastructure to support the future grid, and project engineers deploying systems can use the information, analysis, and lessons learned that will come out of this project. Results will be presented through webcasts, workshops, and white papers.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NIST Smart Grid Standards Tracking, Analysis and Contribution:</strong> Monthly webcasts will focus on the analysis of the NIST SGIP activities. Specifically, how the Priority Action Plans (PAP) activities will impact utilities. A different PAP will be addressed each month. White papers will be developed on the topic of adoption of standards by the industry.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Smart Grid Informational Webcasts:</strong> Monthly webcasts on topics of interest relating to smart grid policy, deployment, technology, and business cases</td>
<td>12/31/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td><strong>Smart Grid Roadmap Interest Group and Workshop:</strong> The smart grid roadmap interest group and workshop brings together the people who have the responsibility for developing their company’s smart grid roadmap to share lessons learned and experiences.</td>
<td>12/31/12</td>
<td>Workshop, Training, or Conference</td>
</tr>
<tr>
<td><strong>Analytical Studies on Topics that Impact the Deployment of Smart Grid Applications:</strong> A series of white papers on topics that are selected by the members at the beginning of the year. These papers will address urgent topics that will impact the deployment of smart grid applications.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Communications Technology Tracking and Analysis:</strong> Regular research updates on the development of communications technology to support smart grid applications</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
PS161B Infrastructure for Intelligent Transmission Systems (063437)

**Project Set Description**

The Infrastructure for Intelligent Transmission Systems project set focuses on the communications and information technology (IT) infrastructure needed to close technology gaps and achieve the interoperability required to support the transmission system of the future. It also addresses the migration strategies that will be essential to the successful transition from the systems of today to the systems of the future. The transmission system is already using extensive and sophisticated instrumentation and applications. This project set will assess additional possible communications needs for real-time applications and will identify strategies to migrate from the existing communications and data models to interoperable, common database models and communications standards by developing enterprise-wide use cases for advanced transmission applications.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>P161.003</td>
<td>Applying the Common Information Model (CIM) for Information Integration of Transmission Applications</td>
<td>This project develops requirements for integrating Smarter Transmission applications within industry-defined areas of interest. These requirements serve as the basis for the development of data and device models for demonstration solutions such as The Standards-Based Integration Specification and Network Model Manager and Repository. This, in turn, validates the readiness of the CIM and IEC61850 standards and contributes to standards activities within key industry organizations such as IEC, IEEE, NIST and others. Additionally, this project provides educational resources to utilities interested in applying the CIM.</td>
</tr>
<tr>
<td>P161.015</td>
<td>Smarter Transmission System Implementation Strategies</td>
<td>This project will create strategies to assist utilities in migrating existing legacy transmission communications technologies to an IEC 61850 based communications infrastructure. The project will include Smart Grid Substation Lab simulations and lessons learned from real migrations if available.</td>
</tr>
</tbody>
</table>

**P161.003 Applying the Common Information Model (CIM) for Information Integration of Transmission Applications (063286)**

**Key Research Question**

Robust and highly integrated communications and computing infrastructures will be needed to create a smarter transmission grid. These infrastructures need to facilitate interoperability across vendor equipment and applications deployed throughout the enterprise. Achieving the necessary level of interoperability requires the development and industry adoption of a tightly coupled suite of standards. The Common Information Model (CIM) represented by IEC 61968 and IEC 61970 provides a common language for integrating applications across the enterprise and is a foundation standard for smart grids. IEC 61850 and the Internet Protocol (IP) also are key standards.

**Approach**

This project will develop requirements and explore solutions for integrating applications that are key to the deployment of smarter transmission technologies. Examples of these applications include the Asset Health Center, the Network Model Manager and Repository, Substation Intelligent Electronic Device (IED) Data Utilities, or other industry-suggested applications that align with the smarter transmission direction. This project will be utility driven and will move beyond the theoretical world into the practical world, focusing on supporting successful deployments of the CIM and IEC 61850 standards. Any identified issues will be presented to the appropriate standards body for consideration during their review cycle. A central part of this project is the application of the existing portions of the standards and demonstration of the value to the business enterprise that will create the necessary momentum to continue the path forward.
In addition to the focus on the practical application of standards development, this project will also provide information and education on the CIM to utilities considering deployment of a CIM-based solution.

**Impact**

This project could have the following impacts:

- Demonstrate true interoperability, and enable integration of applications across the enterprise via systems built to open standards.
- Verify standards that enable open enterprise applications, and utilize this openness across utilities.
- Enable improved life-cycle savings by demonstrating the value of “end-to-end” business process streamlining of data management.

**How to Apply Results**

Utility control center information technology project managers, automation project engineers, operators, and transmission planners will use the tools and knowledge produced in this project to apply the CIM standard within their organization. Results from this project will help members plan for future requirements involving upgrades to their energy management systems, substation data managers, etc., and for the procurement of next-generation transmission operations equipment such as relays and protection equipment.

**2012 Products**

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>The Standards Based Integration Specification:</strong> This product brings together work from several areas to demonstrate the potential value of correlating multiple sources of asset-related information so that intelligent decisions regarding the operation and maintenance of assets can be made. For example, EPRI has developed algorithms to assess the health of large power transformers. This assessment, while effective, is somewhat static in its application. Through the efforts of this product, a real-time assessment process will be demonstrated that integrates necessary information from applicable systems and provides the appropriate information to utility staff across the enterprise. Additionally, there are data from various asset health sensors typically installed to remotely collect data from major pieces of equipment across the transmission system. This sensor data, translated into IEC 61850, could be integrated into a CIM-based integration environment and provided on a near real-time basis to appropriate field personnel, equipment experts, and asset managers to perform forensic analysis and enhance their asset-management strategies (such as repair or replace, life extension, sparing strategies, maintenance strategies, and specification for replacement equipment) and to grid operators to enhance their decision making.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>

The CIM and 61850 standard interfaces required by this product are substantially complete in their design, but have not yet been field tested. Any identified issues will be presented to the appropriate standards body for consideration during their review cycle.

| **Network Model Manager and Repository:** The duplication of effort in maintaining multiple transmission system network models in disparate applications is a challenge facing utilities that will grow more complex as the number of applications dealing with network models increases. Applications supporting substation automation configuration, protection scheme definitions, and interfaces to distribution system models will be added to the current planning applications and EMS systems that contain transmission system network models. This product focuses on the definition of requirements and a solution demonstration for a Network Model Manager and Repository that will support the life cycle of the transmission network (from planning through construction, configuration, and commissioning to reconfiguration and | 12/31/12              | Technical Update   |
Product Title & Description

Planned Completion Date | Product Type
--- | ---

**retirement). A Network Model Manager and Repository would be used to maintain transmission models used by all other applications in EPRI's Smart Grid Substation Lab. Data export would use CIM (61970 and 61968) defined interfaces and would utilize both “flat file XML” and integration bus approaches. Any identified issues will be presented to the appropriate standards body for consideration during their review cycle.**

**CIM Education:** This product will provide support for a variety of CIM users group (CIMug) activities including meeting summaries and training materials. It also provides a venue for complementary CIM training; for access to reference information about the CIM standards; and for learning about CIM deployment experiences, CIM-based products, and implementation resources. 12/31/12 Workshop, Training, or Conference

**Future Year Products**

Product Title & Description

Planned Completion Date | Product Type
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**The Standards Based Integration Specification:** This product will continue to refine the efforts of bringing together work from several areas to demonstrate the potential value of correlating multiple sources of asset-related information so that intelligent decisions regarding the operation and maintenance of assets can be made. For example, EPRI has developed algorithms to assess the health of large power transformers. This assessment, while effective, is somewhat static in its application. Through the efforts of this project, a real-time assessment process will be demonstrated that integrates necessary information from applicable systems and provides the appropriate information to utility staff across the enterprise. Additionally, there are data from various asset health sensors typically installed to remotely collect data from major pieces of equipment across the transmission system. This sensor data, translated into IEC 61850, could be integrated into a CIM-based integration environment and provided on a near real-time basis to appropriate field personnel, equipment experts, and asset managers to perform forensic analysis and to enhance their asset-management strategies (such as repair or replace, life extension, sparing strategies, maintenance strategies, and specification for replacement equipment) and to grid operators to enhance their decision making.

The CIM and 61850 standard interfaces required by this project are substantially complete in their design, but have not yet been field tested. Any identified issues will be presented to the appropriate standards body for consideration during their review cycle. 12/31/13 Technical Update

**Network Model Manager and Repository:** The product will continue the effort started in 2012 to reduce the duplication of effort in maintaining multiple transmission system network models in disparate applications. This is a challenge facing utilities that will grow more complex as the number of applications dealing with network models increases. Applications supporting substation automation configuration, protection scheme definitions, and interfaces to distribution system models will be added to the current planning applications and energy management systems that contain transmission system network models. This product focuses on the definition of requirements and a solution demonstration for a Network Model Manager and Repository that will support the life cycle of the transmission network (from planning through construction, configuration, and commissioning to reconfiguration and retirement). A Network Model Manager and Repository would be used to maintain transmission models used by all other applications in EPRI's Smart Grid Substation Lab. Data export would use CIM (61970 and 61968) defined...
interfaces and would utilize both “flat file XML” and integration bus approaches. Any identified issues will be presented to the appropriate standards body for consideration during their review cycle.

**CIM Education:** This product will continue to provide support for a variety of CIM users group (CIMug) activities including meeting summaries and training materials. It also provides a venue for complementary CIM training; for access to reference information about the CIM standards; and for learning about CIM deployment experiences, CIM-based products, and implementation resources. 12/31/13 Workshop, Training, or Conference

### P161.015 Smarter Transmission System Implementation Strategies (069294)

#### Key Research Question

The recent acceleration of the implementation toward a smarter transmission grid within the confines of the existing infrastructure has significant challenges. Since the transition will take a number of years, operating in the mixed state of partial smart grid and partial legacy technology will not be easy. Research is needed to determine how a utility transitions to a smart grid while maintaining continuity of service during the transition and to determine what options are available to have smart equipment co-mingled with legacy devices. Also, the benefits and disadvantages to different implementation strategies are uncertain. For example, should a company implement by voltage class, geographic region, or some other approach? What are the pros and cons of the various approaches?

#### Approach

This project will document the proposed and actual transition approaches of various utilities to implementing a smart grid and assess issues associated with the implementation strategy. EPRI will also look at the various approaches proposed or being implemented by various utilities deploying smart grid technologies and assess the pros and cons. Actual lessons learned will be documented and communicated.

#### Impact

This project could have these impacts:

- Members will be able to better understand the pros and cons of various implementation methods and the challenges associated with each.
- Members will be able to plan, design, develop, and execute a better smart grid implementation strategy for their companies and better understand the benefits achieved using different approaches.

#### How to Apply Results

Members will be able to apply the knowledge gained from the project products to designing and implementing smart grid technologies effectively through the transition from legacy environments to smart grid.

### 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Synchrophasor Communication Infrastructure:</strong> This project will continue the process started in 2011 to evaluate the benefits of various approaches to wide-area communications used for the transport of synchrophasor measurements. This will include both transport within the utility as well as outside the utility to external entities such as RTOs and ISOs. The project will also assess the NASPInet concept developed by the North American Synchrophasors Initiative's Data and Network Management Task Team being implemented by the American Recovery and Reinvestment Act (ARRA) award winners.</td>
<td>12/31/12</td>
<td>Technical Update</td>
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</table>
may include demonstration of the NASPInet concepts within EPRI's Smart Grid Laboratory as appropriate and evaluation of the tactical development of the various components.

**IEC 61850 Implementation:** Implementing IEC 61850 within a utility is not necessarily easy or straightforward. While transitioning electromechanical relays to microprocessors is a relatively straightforward process, taking advantage of the entire suite of benefits enabled by IEC 61850 enabled devices is another matter altogether. What approach to the transition is most beneficial? At what point should a utility consider adoption of the process bus, object models data, communication protocol transition, and more? Each of these features brings benefits that need to be carefully considered within the context of the rest of the substation, control center, and enterprise.

In this project, EPRI will evaluate and assess various implementation strategies from the perspective of “how to deal with all the IED data” and the benefits and drawbacks of various approaches applied in the field. The project will also look at what tools exist to assist in the management of the data.

**Transition from Legacy Protocols to IEC61850:** Implementation of IEC 61850 within a utility is not necessarily easy or straightforward. During the transition, it is usually necessary to operate with both legacy protocols and the new IEC protocol simultaneously within a substation environment. This project will look at the implication of this dual-protocol mode and offer guidance as to successful approaches to consider during the transition.

**Future Year Products**

**Synchrophasor Communication Infrastructure:** This project will wrap up the process started in 2011 to evaluate the benefits of various approaches to wide-area communications used for the transport of synchrophasor measurements. This will include both transport within the utility as well as outside the utility to external entities such as regional transmission organizations (RTOs) and independent system operators (ISOs). The project will perform a final assessment of the NASPInet concept developed by the North American Synchrophasors Initiative's Data and Network Management Task Team as implemented by the ARRA award winners.

**IEC 61850 Implementation:** Implementing IEC 61850 within a utility is not necessarily easy or straightforward. While transitioning electromechanical relays to microprocessors is a relatively straightforward process, taking advantage of the entire suite of benefits enabled by IEC 61850 enabled devices is another matter altogether. What approach to the transition is most beneficial? At what point should a utility consider adoption of the process bus, object models data, communication protocol transition, and more? Each of these features brings benefits that need to be carefully considered within the context of the rest of the substation, control center, and enterprise.

In this project, EPRI will evaluate and assess various implementation strategies from the perspective of “how to deal with all the networked IEDs” and the benefits and drawbacks of various approaches applied in the field. The project will also look at what tools exist to assist in the management of the IEDs.
Transition from Legacy Protocols to IEC61850: Implementation of IEC 61850 within a utility is not necessarily easy or straightforward. During the transition, it is usually necessary to operate with both legacy protocols and the new IEC 61850 protocol simultaneously within a substation environment. This project will look at the implication of this dual-protocol mode and offer guidance as to successful approaches to consider to actually phase out the legacy protocol at the substation.

12/31/13

Technical Update

PS161C Infrastructure for Intelligent Distribution Systems (063438)

Project Set Description

The Infrastructure for Intelligent Distribution Systems project set focuses on the communications and IT infrastructure necessary to achieve fully integrated distribution operations. The research is focused on obtaining, sharing, using, and updating information that is critical for distribution applications. The standards for back-office application integration and communications are evolving rapidly. This project set seeks to track this evolution and provide value to the participating members with analysis and ancillary information in the form of training, tools, and media. The project set further seeks to utilize back-office standards and communications protocols to provide near-term value to utilities in the form of tools and techniques for using information.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P161.005</td>
<td>Enterprise Information Sharing for Smart Distribution Applications</td>
<td>This project supports cost-effective utility integration of distribution applications by advancing CIM-based design, implementation, and interoperability testing. The project will focus on tracking CIM development progress and developing guidelines for the application of the standards to real back-office integration.</td>
</tr>
<tr>
<td>P161.018</td>
<td>Geospatial Information System (GIS) Data Quality Improvement</td>
<td>The project intends to provide utilities with an adaptable template and set of tools that can be used to assess, improve, and ensure ongoing GIS data quality.</td>
</tr>
<tr>
<td>P161.019</td>
<td>Field Force Data Visualization of Operational Data</td>
<td>This project is to develop a polished mobile data access application using modern web standards (for example, HTML5) in conjunction with modern mobile operating systems (for example, Apple iOS4 or Google Android) to create an application to merge data from disparate systems with real-time video to create a user interface for the visualization and dissemination of operational data.</td>
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</table>

P161.005 Enterprise Information Sharing for Smart Distribution Applications (065546)

Key Research Question

Utilities need Common Information Model- (CIM-) based architecture, infrastructure, applications, and interoperability testing to support efficient cost-effective enterprise integration of distribution applications. This project focuses on tracking CIM development progress and developing guidelines for the application of the standards to real back-office integration.

Approach

This project will continue to support interoperability tests of the CIM for distribution messages and report on the results. The project will also monitor the progress of the CIM for distribution standards as a whole, and will assess the progress and convey to the funders the impact of the CIM development on their day-to-day business
functions. This project will survey the state of the industry of CIM integration and will provide guidance as to the viability of implementing parts of the CIM or CIM-like semantic models.

**Impact**

IT and operations personnel can expect to gain a deeper knowledge of the problems they may face in implementing CIM or any other back-office standard. These individuals will gain knowledge of solutions to problems that they may face by learning from other efforts.

**How to Apply Results**

Distribution system architects, application developers, and information technology managers can use the knowledge and products produced in this project for designing, developing, testing, and maintaining distribution applications.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td><strong>Update on CIM for Distribution Development and Testing Activities for 2012:</strong> A compendium of the activities involved in the development and testing of IEC 61968 and MultiSpeak®.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Application of the CIM in Distribution Enterprise Applications:</strong> Case studies and training in the use of the CIM, using the experience gained by members in overcoming real problems.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>

**P161.018 Geospatial Information System (GIS) Data Quality Improvement (072073)**

**Key Research Question**

Utilities continuously struggle with the quality of geospatial information system (GIS) data. With the advent of the smart grid and advanced metering infrastructure, utilities are facing increased pressure to resolve data quality issues. GIS quality issues are primarily related to:

- Gaps. For example, certain key data are missing.
- Redundancies with other systems. For example, data are captured in many systems, and they are inconsistent or require duplicate data entry to update.
- Lack of currency with system “as-built.” For example, there is untimely work order completion/backlog.
- Inaccuracies with the field. For example, The GIS has data, but does not represent the actual system in the field.
- Inaccurate or unavailable land base. For example, there are varying degrees of accuracy of land-based data based on the source.
- Customer to transformer connectivity by phase is in doubt.
- The GIS model itself allows for “bad” data.

The project intends to provide utilities with an adaptable template and set of tools that can be used to assess, improve, and ensure ongoing GIS data quality.

**Approach**

With the advent of advanced metering infrastructure (AMI), distribution management systems (DMS), distributed energy resources (DERs), and the smart grid, distribution companies can no longer ignore poor data quality. In many cases, utilities are finding that their capital-intensive smart grid investments are not yielding anticipated benefits simply because the utility does not have an adequately accurate representation of the distribution
system. In more extreme cases, the safety of employees and the public has been compromised due to misrepresented facilities in the GIS.

Utilities need a robust and reliable model from customer to transformer through protective devices to substation by phase that is accurate and timely. This project will do the following for participants:

- Provide a means of performing a self-assessment of data quality, what is needed, how accurate it should be, and where they are in comparison to peers.
- Identify processes, strategies, tactics, and tools to resolve existing data challenges.
- Provide processes and methods to ensure that data quality continues to improve.
- Offer software tools specific to key utility GISs to assess, correct, and ensure ongoing data quality.

The project intends to provide utilities with an adaptable template and set of tools that can be used to assess, improve, and ensure ongoing data quality. The project will serve as a seminal reference to data quality for utilities. Following the recommendations of the report and using the associated tools will provide utilities with a strong foundation to ensure data quality on an ongoing basis.

Impact

The GIS acts as the “hub” around which the engineering and operations applications revolve. In an ideal world, the GIS feeds critical information to the other applications in the distribution environment. This ideal has been hampered by the lack of complete and accurate data. By cleaning up the data in the GIS, a utility that relies on that data could expect immediate improvement in the accuracy of the Outage Management System (OMS), power systems modeling, DMS, and other mission-critical applications.

How to Apply Results

IT and engineering departments will be able to take the findings of this work and apply them to their business processes. The results of this research will be written as a series of actionable steps that, taken individually or collectively should be able to mitigate the GIS data issues that utilities actually face.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td>Geospatial Information System (GIS) Data Improvement: Processes, strategies, tactics, and tools to resolve existing GIS data challenges and help prevent future issues.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>

P161.019 Field Force Data Visualization of Operational Data (072074)

Key Research Question

Utilities continuously struggle to justify their investment in information technology. Inaccurate data, lack of standards, and vendor “lock-in” all prevent the cost-effective use of their technology investment. Data exist in disparate systems, inaccessible to the operations center and field personnel. Mobile computer power is wasted, displaying out of date or irrelevant data. Data are not used because they are not available in the vendor-specific software that is loaded on the mobile computing device. In short, the investment made in IT by utilities has yet to reach its full potential. To fully realize the promised potential, a standards-based IT architecture is needed for the visualization of data and the use of visual data in the decision-making process. In that respect, what is needed is:

- A generic data viewer that can work with any data, but that can be easily customized/configured for particular types of data
• Seamless integration of data systems so the user is not aware that they are pulling data from multiple systems
• The ability to add new systems on the fly to increase the available data
• A polished, modern smart user interface (UI) that utilizes all the advances made in graphical user interfaces that have been developed in other industries
• A standard graphics format so the user has access to a graphical editor that works for multiple types of data
• Multi-platform functionality so that it works on a computer, phone, tablet, etc.

This project is to develop a polished mobile data-access application using modern web standards (for example, HTML5) in conjunction with modern mobile operating systems (for example, Apple iOS4 or Google Android) to create an application to merge data from disparate systems with real-time video to create a user interface for the visualization and dissemination of operational data.

Approach

As utilities begin to integrate systems that previously operated with little or no data interconnection, it becomes easier to link together related data. This can result in powerful diagnostic and management tools that use this interconnected data so that engineers can better understand the network and the context of any unexpected behavior. To show the power of data integration and modern human-computer interfaces, it is proposed that emerging technologies from the mobile computing field be used to create a Mobile Integrated Data Access Platform.

A key use-case is to allow a lineman or engineer out in the field to be able to identify all relevant data for the network at their current location. From this interface they could navigate through all the data for a transformer; identify its location in the GIS and a single-line diagram; be shown the down-stream circuit on a map; and trace into its asset history, maintenance history, manufacturer information and catalogue, etc. Upon arriving in a street, the GIS and magnetometer (compass) built into a tablet would identify the crew’s location, and holding up the tablet would allow them to see in real time a video of the area with data on the view, on a single line diagram, and on the map. The lineman could query as to the state of a switch, identify premises with outages, automatically tag devices, etc. This would all be possible with a properly integrated data environment and accurate GIS data.

Impact

This project is a first step in utilizing the power of the Common Information Model (CIM) with a lightweight graphical interface. A utility will be able to combine the field force functionality of GIS, OMS, Asset Management, and Work Management. The field device of the future could provide the lineman with one interface on an inexpensive platform to perform all their necessary functions. Operational efficiencies could be expected along with the potential for lower IT hardware costs, fewer application seat licenses, and an overall lower cost of ownership of the field force platform.

How to Apply Results

Distribution system architects, applications developers, and information technology managers can have a powerful new tool to deploy to the field force to enhance capability and lower costs.

2012 Products

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<tr>
<th>Product Title &amp; Description</th>
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<tbody>
<tr>
<td>Mobile Integrated Data Access Platform: Software proof of concept to leverage CIM messaging and combine multi-application functionality in the field.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
</tbody>
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PS161D Infrastructure and Technology for Customer Integration, Including Metering and Demand Response (063439)

Project Set Description
This project set addresses the communication integration of customers with the utility, including advanced metering, load management, distributed energy resources (DERs) such as photovoltaic (PV) and battery storage, and other general information exchange. In the past, the customer interface was primarily limited to monthly metering, but advances in communication, measurement, and control technologies have transformed the landscape of customer integration, bringing many new possibilities but also many challenges. This project set addresses these challenges by evaluating technologies and architectures, identifying standards gaps and accelerating development, identifying lessons learned and best practices, and demonstrating capabilities in both laboratory and field environments.

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<tr>
<th>Project Number</th>
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<tr>
<td>P161.016</td>
<td>Advanced Metering Systems: Technologies, Architectures, and Life Cycle Management</td>
<td>The project will conduct research to advance the state of the technology for metering communication systems, including functionality, performance, and employment of open standards. Ancillary uses, such as DER management and distribution controls, will also be evaluated. Best practices for life cycle management will be tracked and reported.</td>
</tr>
<tr>
<td>P161.017</td>
<td>Load Management and DER Integration Systems: Technologies, Architectures, and Life Cycle Management</td>
<td>This project will conduct research regarding the communication systems and protocols used for end-load and DER monitoring and management, including residential, commercial and industrial domains. Emphasis areas will include acceleration and evaluation of open standards, and testing for interoperability.</td>
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P161.016 Advanced Metering Systems: Technologies, Architectures, and Life Cycle Management (072075)

Key Research Question
Utilities are deploying advanced metering infrastructure (AMI) in their service territories, creating two-way communication networks reaching customer premises. Although metering is the primary application of AMI, the systems are generally viewed as being multi-purpose, sometimes supporting demand response, distribution controls, and renewables integration. Presently, there are many of providers of AMI systems, employing a wide range of technologies that include power-line communication, wireless, and wired broadband. Due to a lack of standards at many levels, these systems are mostly proprietary, and utilities are locked in to a particular vendor once they begin to deploy. AMI is evolving rapidly, with providers working to stay in step with changing utility needs and the availability of existing public infrastructure expanding. For most utilities, their next AMI system may bear little resemblance to their present system.

Objective evaluation of these systems is needed, understanding the potential for the different architectures to support the range of applications. Acceleration of standards development is also needed in order to improve the interoperability of systems and to foster competition by enabling multiple sources of supply.

The project will conduct research to advance the state of the technology for metering communication systems, including functionality, performance, and employment of open standards. Ancillary uses, such as distributed energy resources (DER) management and distribution controls, will also be evaluated. Best practices for life cycle management will be tracked and reported.
**Approach**

This project will closely coordinate with others within EPRI and throughout the utility industry. New applications and requirements identified in application areas, such as electric transportation, storage and renewables integration, advanced distribution, and demand response, will feed into the work of this project. Specific demonstration projects will be collaboratively conducted and results shared.

This project will work with participating utilities to perform evaluations and to conduct testing of AMI architectures and protocols and will document the results in EPRI technical reports. Industry contributions will be made with the goal of stimulating or accelerating the development of open standards by identifying gaps and recommending solutions. The project will seek to identify best practices for life cycle management of AMI technologies, studying the design, deployment, operation and end-of-life issues to reduce the total cost of ownership for utilities and to maximize the benefits to customers.

**Impact**

Members will contribute to establishing a long-term industry vision for AMI, providing valuable input to system providers as to the nature of next-generation products that will be needed and contributions to standards bodies regarding gaps and needs for the future. An understanding of outside influences in the 10-year horizon, including technology advancements, infrastructure availability, third-party applications, and evolving customer expectations, will help to shape the vision. This vision will serve as a foundation for a strategic plan that will help guide research in the IntelliGrid program going forward. Standards organizations (for example, IEC, ISO, ANSI, and NIST) may benefit from the results of this project.

**How to Apply Results**

Members will gain insight into the range of advanced metering technologies being offered, the capabilities afforded by each, and the system uses being considered by other utilities. These insights will help members in executing their own assessment of various communication networks and in planning what uses, in addition to metering, might be supported by their AMI. Sharing of lessons learned will aid member utilities in developing their own processes and will enable the compilation of best practices regarding system architecture, ancillary system uses, deployment, operations, upgradeability, and transition to next-generation systems.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tr>
<td><strong>Secure and Cost Effective Sub Metering:</strong> Driven by the sub-metering needs of electric transportation and distributed photovoltaics, this project will assess options for secure and cost-effective sub-metering. This will be a multi-phase undertaking.</td>
<td>12/30/12</td>
<td>Technical Update</td>
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<tr>
<td><strong>Open Systems-Based Advanced Metering:</strong> Building on supplemental activity started in 2011, this multi-year project will work to identify methods, standards, and specifications leading to AMI systems free of vendor lock-in. Phase 1 will include an analysis of existing and emerging standards on which open systems can be built. The work will include extensive coordination with industry organizations, including NIST and UCAI OpenSG.</td>
<td>12/30/12</td>
<td>Technical Update</td>
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</table>
P161.017 Load Management and DER Integration Systems: Technologies, Architectures, and Life Cycle Management (072076)

Key Research Question

With challenges in bringing new generation online, both load management and distributed generation resources have become increasingly important to utilities. Load management exists in many forms, including variable pricing programs and direct load control; and it serves many uses, including load shifting for economic purposes and fast curtailment for emergency reserves. Distributed generation includes both utility- and customer-owned PV and battery storage systems.

Utilities are employing a wide range of communication architectures to facilitate their load management needs. All systems involve some form of a wide-area communication system used to reach customer premises. These include systems that may be one-way or two-way, public or private, wired or wireless. Some systems also include a secondary in-premise network, such as a building automation system or home area network, and may or may not involve an energy management console. At all levels, load management systems employ diverse technologies, many of which are evolving rapidly, both in terms of the physical communication devices and the protocols they transport. Different architectures have different capabilities and, as a result, may be more or less suited for a given use.

Research is needed to better understand the capabilities and limitations of various communication architectures. Standards are needed to simplify and reduce the cost of establishing connectivity with end devices. At the furthest reach or “edge” of the utility’s communication system, interoperability with end devices and the ability to accommodate evolution of customer equipment is critical. Improved understanding of customer preferences regarding connectivity and control is crucial to increasing enrollment and continuance in load management programs going forward.

This project will conduct research regarding the communication systems and protocols used for end-load management, including residential, commercial, and industrial domains. Emphasis areas will include acceleration and evaluation of open standards and testing for interoperability.

Approach

The project will perform evaluation and testing of communication architectures, technologies, and protocols employed for load management and integration of distributed energy resources. Activities will be carried out in coordination with other industry activities, including those of NIST, IEEE, and Open SG, avoiding overlap and making contributions where possible. Analysis and interoperability testing of emerging protocols, such as smart energy profile (SEP) and OpenADR will be conducted and results contributed to the appropriate organizations to help accelerate and mature their work. Forward-looking research elements will identify and demonstrate new applications, including integration of intermittent renewables, charging support of electric vehicles, and value-adding ancillary services such as dynamic grid stabilization and voltage regulation.

Impact

Participants will benefit from neutral evaluations of the architectures, technologies, and protocols involved with load management in the industrial, commercial, and residential domains. Findings will be used to provide valuable input to various end-device manufacturing groups such as American Household Appliance Manufacturers (AHAM), Air Conditioning, Heating and Refrigeration Institute (AHRI) and American Society of Heating, Refrigeration and Air Conditioning (ASHRAE). This relationship will foster improved understanding of utility demand-response needs and end-device capabilities. Where applicable, research results will be contributed to standards organizations to help improve, expand, and mature the standards that are critical to load management and the general utility/customer interface.
How to Apply Results

Members will have access to assessments, guidelines, and evaluation tools to aid in their load management and distributed resource systems design and technology selection processes. Understanding of the state of present and planned standards will assist members in working with product providers, leading to more open, interoperable systems.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td><strong>Modular Communication Interface for Residential Devices: Industry Assessment:</strong> This project will perform an assessment of global efforts to define standard modular interfaces for residential devices. It will gauge standards progress, maturity, and stakeholder support to provide insight into this architectural possibility, its limitations, and potential benefits.</td>
<td>12/30/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Standard Interfaces for Smart Building Integration:</strong> This project will investigate the methods and standards by which utilities may integrate smart buildings into their distribution systems. The work will include a summary of related activities, NIST PAPs, and current activities in standards groups in addition to an assessment of the market penetration of various protocols, and will provide an overall reference guide to smart building integration.</td>
<td>12/30/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Smart Energy Profile 2.0 Device Compliance:</strong> This project will build upon supplemental project activity started in 2011. It will expand the capabilities of the software test harness to allow remote evaluation of products against a reference SEP 2.0 implementation. Results will be provided to SEP 2.0 protocol developers as well as to product manufacturers to aid in finding ambiguities in the specification and to accelerate its overall development.</td>
<td>12/30/12</td>
<td>Technical Resource</td>
</tr>
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</table>
Supplemental Projects

Smart Grid Roadmap Development (072077)

Background, Objectives, and New Learnings
A smart grid merges communications and information technology with the power system infrastructure to achieve objectives such as:

- Extracting additional capacity from the existing infrastructure through peak load management
- Reducing costs through advanced metering infrastructure
- Maximizing transmission throughput through wide area measurement and control using phasor measurement techniques
- Increasing reliability through on-line health monitoring of key components

Smart grid development is usually different for each utility. Approaches are influenced by regulatory policy and business drivers and the mix of technologies that a company has currently installed. Therefore, it becomes necessary for each utility to develop a Smart Grid Roadmap that defines the applications, technologies, policies, practices, and priorities that they should implement.

EPRI has been helping utilities determine their path through the smart grid by applying a disciplined methodology developed early in the IntelliGrid program. This process, when applied to the task of uncovering which smart grid applications should be implemented by a utility over time to maximize their value, is the core of EPRI’s Smart Grid Roadmap program.

A roadmap developed in this project as the final deliverable will be specific to the requirements and existing infrastructure, but will also contribute to more general industry infrastructure and technology requirements. Generic versions of selected use cases and roadmap development procedures will be available for the collaborative effort. The knowledge is being incorporated into the EPRI R&D programs. The roadmap for migration to an intelligent grid is an integral part of the Intelligrid Program (P161) and the results of the project will contribute to the use case library that is part of this program.

In addition to publication of project results in EPRI research reports, important summaries of the project results will be made available through appropriate industry publications (for example, IEEE journals, IEEE meeting panel sessions, international conferences, etc.).

Project Approach and Summary
The project will produce a customized smart grid roadmap document for the funder that is focused on specific needs, which may be technology or policy related, and priorities and incorporates lessons learned from other roadmap development projects.

The resulting roadmap will help the utility accelerate the deployment of projects and system components that, when leveraged as a whole, constitute a smart grid. It also will help the collaboration by sharing another set of lessons learned on the road to the smart grid.

The roadmap development project is broken into several tasks, some performed in workshop settings and others carried out by performing analysis and mapping requirements and technologies as necessary. The key activities include information gathering and review as well as an initial project kickoff meeting and workshop with the utility’s smart grid team to familiarize the EPRI team with key personnel and documents provided to the EPRI team.

At the core of the roadmap development is the use case preparation and requirements specifications development. Use cases may be retrieved from repositories prepared previously with other utilities or may be
uniquely developed for new participants. Requirements and use cases cover both functional and system management requirements.

Once the requirements are set, a range of technologies will be identified that can meet the requirements, and existing technology will be assessed regarding how it can support the utility’s strategy, followed by a cost-benefit analysis.

The final tasks focus on synthesizing all of the information gathered in order to prepare a draft roadmap document. This will be done in close cooperation with utility personnel. Key elements include priorities and migration options for existing infrastructure as well as technology demonstrations to confirm technology assessment when necessary and definition of an overall implementation plan.

This project will benefit the public by providing guidelines and best practices for implementing smart grid applications. This information will optimize the cost and benefit for building the smart grid and reduce the risk of early obsolescence.

Benefits

The activities of this project are intended to deliver the following value for the project participants:

- Clarity on options available and the impact they may have
- Understanding of the key smart grid applications and their requirements that will utilize the communications architecture, and how the applications support the utility’s vision and impact existing projects
- Possible buy-in throughout the utility for the roadmap through inclusion of key personnel during its creation
- Understanding the possible role of existing infrastructure and technologies

The public will benefit through the increased understanding of what are the key contributing factors when implementing smart grid applications, as well as their impact on costs and benefits.
Common Information Model (CIM) for Distribution Development (072078)

Background, Objectives, and New Learnings
EPRI has a long history of assisting in the development of the Common Information Model (CIM). The model for development has been for volunteer labor to develop and test the model and resulting messages between systems. The vast scope of the CIM has taxed this method of development to the limit, and it is now time to organize and fund an effort to rapidly develop the standard for broad dissemination.

In previously funded EPRI research, standard test procedures were developed for conformity and interoperability. This was done to prepare for this effort, which is a full-scale project to develop standard messages for CIM. This project is part of an EPRI strategy to remove the barriers to vendors providing CIM-compliant applications to the industry.

New learnings that will be brought about from this work include the service definitions (messages) needed to achieve basic interoperability for most back-office utility applications. New additions and extensions to the CIM will also be researched and added to the model as warranted.

Project Approach and Summary
This project is part of a multi-year strategy to eliminate the barriers for widespread CIM implementation across the entire enterprise. Other projects in this multi-year strategy include developing standard testing procedures for conformity and interoperability testing, developing a CIM primer to reduce the learning curve with the standard and harmonization projects with other standards such as IEC 61850 and MultiSpeak®.

The project intends to develop model improvements to IEC 61968 and to create and test new service definitions (messages). The project will coordinate with existing groups, such as OpenSG and IEC TC 57 WG 14 to accomplish this. While developing the model for IEC 61968, the project team will harmonize the new results with IEC 61850, MultiSpeak®, SEP 2.0 and other applicable standards.

This project will consist of engaging a team of CIM professionals, dedicated to developing the use cases, messages, and additions to the CIM model to achieve a well-defined set of functionality that will encompass the entire breadth of the CIM.

Benefits
Smart Grid implementations are being hampered by a lack of standards to achieve the necessary level of back-office integration, reduce the cost of application ownership, and achieve the targeted effectiveness. This project will be an organized, funded approach to CIM development following an agreed-upon project plan. The benefits to the public will include:

- Greater reliability of the electric grid because the development of these standard messages will enable the back-office integration necessary for the smart grid
- Lower rates from the utility being able to reduce the cost of application integrations, typically half to three-quarters of the cost of an application implementation

The benefits to the utility include:
- The distribution back-office applications acting in concert as if they were one system
- The ability to choose best-of-breed solutions and avoid vendor lock-in

The benefits promised by the smart grid will accrue to the public more rapidly and with less risk with the use of integration standards.
Automated Demand Response and Ancillary Services Demonstration (072079)

Background, Objectives, and New Learnings

This demonstration project will perform research associated with emerging energy price and product messaging-protocol standards to take advantage of ubiquitous low-cost communication infrastructures that may be able to reliably perform automated demand response (DR) and ancillary services or fast DR functions. Internationally recognized standards for DR and ancillary services are a key enabler for the development of commercially available products that have largely been proprietary over the last 30 years.

Emerging standards development in this area from the Lawrence Berkeley National Lab, the Organization for the Advancement of Structured Information Standards (OASIS) and the National Institute of Standards and Technology (NIST) have advanced sufficiently so that demonstrations are feasible and products are beginning to become commercially available, but research questions remain about the level of quality of service, reliability, security, and scalability. Other issues include the level of measurement and verification required and an understanding of the load characteristics and how it can meet the ancillary services requirements. In support of the research and advancement of this industry effort, EPRI will contribute to open source versions of Open Automated Demand Response (OpenADR) servers and clients that can be also be used by members of this project.

Project Approach and Summary

As a part of a path toward realizing the benefits of OpenADR, this project will focus on the interactions between the utility and a facility while validating OpenADR platforms and systems. Standardized DR automation is an important component of the smart grid to deliver dynamic price signals to achieve economic or reliability objectives. Via a standardized communications data model, utilities and independent system operators (ISOs) can directly interface with building and energy management systems.

This project will synchronize with the aforementioned groups to continue progress to automate DR programs and acceptance by a wide range of building and industrial controls manufacturers and device manufacturers.

OpenADR is currently defining/developing “Fast DR” capabilities for utilization where shorter cycle times are required to qualify for participating in ancillary service markets. The project seeks to validate fast DR technologies to qualify specific loads for regulating reserve, load following, and spinning reserves by field testing and demonstrations. The intent is to include demonstrations where commercial and industrial (C&I) customers can reduce power usage automatically and quickly to meet the desired target responses reliably and explore how residential products may participate in this market.

Year one (2012) will focus on educating members on the “state of the industry” and developing research plans and demonstration protocols for host sites and contributing to open source developments of a Demand Response Automation Server (DRAS) and clients.

In Year two (2013) utilities will deploy OpenADR servers and clients, operate the system, and assemble the data that will serve as the basis to analyze the performance and benefit.

Small demonstrations for non-host sites will use an EPRI DRAS and clients installed remotely at utility-designated loads and resources.

In Year three (2014), EPRI will complete performance and benefit assessment and report results with all project deliverables consolidated in a final “Reference Guide deliverable.

Benefits

This project may help to accelerate development of standards that automatically manage loads and distributed energy resources (DER) for DR and ancillary services requiring faster response. The use of standardized communication protocols for these functions will benefit the public by enabling the use of multiple types of low-
cost ubiquitous communication networks, crossing many utility boundaries from distributor to ISOs and facilitating access to ancillary markets. In just the short development time of OpenADR v1.0, there are now over 60 energy management and control system vendors that offer OpenADR products (clients). This work is expected to increase market participation in the development of devices, eventually, with this functionality directly built in.

Electric utilities are expected to gain an understanding of the performance capabilities load types, infrastructure requirements, product availability, and market opportunities associated with the advancement of this smart grid application.
Field Area Network Demonstration Project (072080)

Background, Objectives, and New Learnings

The field area network (FAN) is an essential layer of a utility's smart grid communications infrastructure. The FAN concept is emerging to be a ubiquitous, high-per-formance, secure, reliable network providing "last mile" backhaul service for distribution supervisory control and data acquisition (SCADA) and advanced metering infrastructure (AMI) systems, as well as network access services for advanced distribution management and automation, distributed energy resources, and any future smart grid applications requiring connectivity from within and beyond the distribution substation.

FAN implementation may involve a range of technologies -- from next-generation AMI networks (standards-based narrowband wireless mesh) to broadband options including Industrial Wi-Fi (a registered trademark of the Wi-Fi Alliance) and 3G/4G cellular infrastructure to wired (copper and fiber) networks for connecting major grid nodes, such as substations or wind farms, to the utility’s corporate network or to providing backhaul for wireless infrastructure.

These heterogeneous networks will constitute a critical layer in the utility's smart grid network, supporting new applications and eventually migrating legacy operational applications such as distribution SCADA onto the FAN. Yet their reliability, among other characteristics, is not well understood. Therefore, one objective of the project is to establish methods and metrics for assessing the reliability of FAN technologies.

A second objective is to work with utilities to incorporate the evaluation of FAN reliability into their FAN field trials, using the metrics and methods established in the project.

A third objective is to raise the level of industry knowledge and practice around FAN reliability by publishing the results of FAN trials that the project will support. In particular, research will be published on high-reliability FAN architecture, design principles, and guidelines for implementation and operation.

The new knowledge generated by this project is expected to include a reference communications architecture featuring the FAN as a common infrastructure for operational and smart grid applications; and a practical understanding of utility FAN characteristics, with a particular emphasis on models and empirical measures of reliability.

Project Approach and Summary

The project approach is modeled on and is very similar to EPRI's Smart Grid Demonstration Initiative. We plan to help utilities design their FAN projects and trials to include a reliability focus and will provide expert assistance in trial or pilot design, execution, and evaluation. The project will include quarterly meetings among project participants for the dissemination of information, experience, and results. We plan to visit host sites to gain hands-on experience in high-reliability FAN design, implementation, and operation. We plan to model the expansion of trials and pilots in to full-scale deployments across project member service territories.

In summary, participating utilities will be assisted at every stage of the research, design, piloting, evaluation, and planning of a highly reliable FAN as the centerpiece of their next-generation smart grid infrastructure.

Benefits

Utilities may benefit by collaborating with others, thereby gaining knowledge and experience with a wide variety of approaches to high-reliability FAN design. They may also benefit from the ubiquity, performance, security, extensibility, and reliability of a FAN designed according to the architectures, principles, methods, and metrics that are explored or established in the project. These project features may drive risk and cost out of the utility's FAN planning and deployment process.

Society may benefit from higher reliability of energy supply, especially due to a distribution system benefiting from the advanced applications that a FAN can support.
Using Standards to Disperse Field Data Across The Enterprise (072081)

Background, Objectives, and New Learnings

In the 2011 “A Smarter Transmission Grid” white paper that EPRI published, three technology pillars were identified as key to a smarter transmission grid -- grid development and operation, asset lifecycle management, and information and communication technologies (ICT). Specifically, smart grid technologies will demand more analytical horsepower and data-handling capabilities. These data will be large in volume and scattered through the interconnected network. The data sources will be diverse, including equipment health sensors, phasor measurement units (PMUs), intelligent electronic devices (IEDs), and weather sensors, among many other types. Some of these data will be harvested in real time; others will be stored in a historian database. The challenge will be to deliver the information to end users and end-use applications with the specified accuracy, security, and speed.

Robust and highly integrated communications and computing infrastructures will be needed to create a smarter transmission grid. These infrastructures need to be interoperable across vendor equipment and throughout the enterprise. Achieving the necessary level of interoperability requires the development and industry adoption of a tightly coupled suite of standards. The Common Information Model (CIM) provides a common language for integrating applications across the enterprise and is a foundation standard for smart grids. IEC 61850 and the Internet Protocol (IP) also are key standards. The objective of this work will be to establish a diverse set of data sources that are representative of what may exist within a smarter transmission grid and apply a standards-based integration methodology to determine where the gaps are.

Work in 2011 targeted transformer health and was demonstrated within the EPRI Smart Grid Substation Lab using data extracts from utilities and buffered near-real-time data. This work will be continued and expanded through this supplemental project. This approach will provide very specific learning with respect to practical utility-centric integration of a variety of data sources and determine within the established scope the limitations of the current IEC 61850, 61968 and 61970 (CIM) standards from a data object perspective.

Project Approach and Summary

This project will continue the work started in 2011, which was related to transformer health data, into the control room. In that project, utility data, both static, such as nameplate, and near real time, such as transformer loadings, were brought into the EPRI Lab, transformed into the applicable standards models, analyzed, and reported back out to the utility. Interest areas may include other substation assets such as circuit breakers, potential transformers, etc., or other well-monitored field assets.

In this project, the specific requirements for a utility-specified topic area from the applications specified with the white paper will be developed -- applications such as Asset Health Center, Substation IED Data Utilities, or other industry-suggested applications that align with the smarter transmission grid direction. Through these various utility-specific supplemental projects, an overall data and integration strategy will emerge to provide utilities with an integrated approach to transmission smart grid information management.

Unlike previous CIM and IEC 61850 interoperability tests that tended to be bulk data exchange-centric, this project will be utility driven and focus on supporting successful deployments of the CIM and IEC 61850 standards. Any identified issues will be presented to the appropriate standards body for consideration during their review cycle.

Benefits

This project could have the following impacts:

- Facilitate true interoperability, and enable integration of applications across the enterprise via systems built to open standards.
- Facilitate standards that enable open enterprise applications and leverage this openness across utilities.
- Provide benefit to the public through higher reliability by including more relevant information in the decisions process.
RF Characterization and Health Studies (072035)

Background, Objectives, and New Learnings

The electric utility industry is striving to achieve greater energy efficiency and reliability, and to eventually reduce dependence on fossil fuels by economically and efficiently decarbonizing the electricity sector. The development of a smarter grid, a strategic modernization of the electric power system to integrate new and more-distributed energy resources including renewables, is essential for achieving these goals.

The future electric power system will include new technologies and applications involving electromagnetic environments that remain poorly characterized and whose potential effects on human health and safety are not completely resolved. These environments range from extremely low frequencies associated with plug-in hybrid-electric vehicles and charging apparatuses up to the radio frequencies (RF) associated with automatic metering infrastructure and telecommunications emitters, such as cell phone base stations and paging antennas.

Health and safety concerns may pose barriers to implementation of new technology. Public concerns about the health and safety aspects of electric power transmission and distribution have been evident for several decades, as concerned citizens request assurances of health and safety as new facilities are sited and built. Recently, health concerns related to RF exposures have re-emerged due to the proliferation of mobile phone use and wireless technology. This concern has migrated to RF exposures from utility infrastructure such as smart meters. Several cities in California are calling for suspension of advance metering infrastructure (AMI) programs until the health issues are further clarified.

Given the increasing concerns raised by the public and decision makers regarding RF exposures as smart meters are installed, an accelerated and comprehensive research program at EPRI addressing RF associated with modernized electric power systems is warranted.

Project Approach and Summary

To address health and safety concerns related to technologies of the modernized and expanded smarter grid, research must identify sources of environmental exposure and characterize both ambient and personal exposure levels. Subsequent steps include evaluation of the effective dose in the exposed organisms (including the human body), clarification of biological impacts and physiological interactions (including environmental and internal modifying factors), and, eventually, characterization of human health responses. During this process the research must draw from a variety of scientific disciplines including epidemiology, laboratory toxicology, cellular and molecular biology, medical sciences, engineering, and physics.

In 2011, Technology Innovation– (TI-) funded projects were launched to evaluate the current state of the science in RF health research and to identify new and emerging RF-enabled technologies. The proposed work described will be informed by the 2011 TI-funded work, and the scope of work may be refined accordingly.

Benefits

This work will build on EPRI’s wealth of experience in health assessment, exposure assessment, and safety research. The proposed research will contribute to a body of scientific knowledge on the nature of the environment created by the new infrastructure, the exposures’ physical interactions with living bodies, and whether those interactions could lead to concern over biological or human health effects. This essential information will inform decision makers, regulatory agencies, and the public, facilitating timely deployment of technologies used to enhance electrical system efficiency and reliability.
Cyber Security and Privacy - Program 183

Program Overview

Program Description
Cyber/physical security and data privacy have become critical priorities for electric utilities. The evolving electric sector is increasingly dependent on information technology and telecommunications infrastructures to ensure the reliability and security of the electric grid. Cyber security measures must be designed and implemented to protect the electrical grid from attacks by terrorists and hackers, as well as to strengthen its resilience against natural disasters and inadvertent threats such as equipment failures and user errors.

The Electric Power Research Institute's (EPRI’s) Cyber Security and Privacy Program addresses the emerging threats to an interconnected electric system through cross-sector collaborative research on cyber security standards, business processes, and technology to protect the electric grid. The initiative also will undertake collaborative research in the industry to develop technologies, best practices, and controls on data privacy for the electric grid.

Research Value
The Cyber Security and Privacy program intends to provide security tools, requirements, and guidelines to its members. The rapid pace of change in the electric sector creates a challenging environment for members to monitor the activities of industry groups, develop an understanding of the security impact of new technologies, and maintain the right internal resources for assessing technologies.

Participation in EPRI’s Cyber Security and Privacy Program could produce the following:
- Better understanding of industry and government collaborative efforts and where members should 'plug in'
- Guidance on developing cyber security strategies and selecting requirements
- Practical approaches to mitigating legacy system risk
- Security tools that members can use to perform security testing
- Early identification of security gaps through lab assessments of security technology

Approach
The Cyber Security and Privacy Program intends to focus on developing security requirements, creating new security technologies, and performing lab assessments of the technologies. The products produced can be used by members as security requirements and architectures, guidance on industry working groups, and security assessment tools and methodologies.

Key deliverables in this program could include the following:
- Continuous mapping of activity in the cyber security and privacy landscape
- Security solutions and implementation guidance for legacy systems
- Assessment of substation security solutions
- Security management tools for transmission and distribution systems
- Security tools and techniques for assessing end-user devices
- Security architecture for distributed energy resources
- Risk management approaches for cyber-physical incidents

Accomplishments
The Cyber Security and Privacy portfolio has delivered several key accomplishments that have helped its members and the industry:
National Electric Sector Cyber Security Organization (NESCO): EPRI was awarded a contract to provide research and development resources for the Department of Energy’s (DOE’s) public-private partnership NESCO. EPRI is leading the working groups focused on vulnerability and threat identification, cyber security standards assessment, and technology testing and validation. The results of this work are creating improved threat models, cyber security requirements, and security technologies.

DNP3 Interoperability Testing: Within the IntelliGrid program, EPRI responded to the need for increased security in the distributed network protocol (DNP) with a multi-year effort to extend the standard to include secure authentication specifications. EPRI supported efforts to update the International Electrochemical Commission (IEC) 62351-5 and IEC 60870-5-7 and develop an interoperability testing framework.

AMI Security Management Guidelines: This project provided electric utilities with guidelines to securely manage their Advanced Metering Infrastructure (AMI) systems, with a focus on the basic metering capabilities and access to the home area network (HAN) gateway. The guidelines aided utilities in the secure deployment and day-to-day management of their AMI system after a utility has purchased their chosen AMI solution.

Current Year Activities
In 2012, this program expects to accomplish these objectives:
- Track industry and government activities and provide technical contributions to key working groups
- Address cyber security for select classes of legacy systems
- Create a foundation for security management for transmission and distribution systems
- Develop security testing tools and methodologies for substation security and end-user devices
- Create security architectures for new smart grid components such as distributed energy resources
- Examine the potential risks associated with cyber-physical attacks

Estimated 2012 Program Funding
$2.0M

Program Manager
Galen Rasche, grasche@epri.com

Summary of Projects

PS183A Cyber Security and Privacy Technology Transfer and Industry Collaboration (072129)

Project Set Description
The landscape of activities in the cyber security and privacy for the electric sector involves numerous industry, government, and regulatory groups. This project set can provide members with an up-to-date view of these activities and support technical contribution to these groups to increase the usability of their work products.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P183.001</td>
<td>Mapping the Smart Grid Cyber Security and Privacy Activities Landscape</td>
<td>This project intends to provide asset owners and operators with regular updates on the smart grid cyber security and privacy activities.</td>
</tr>
<tr>
<td>P183.002</td>
<td>Cyber Security and Privacy Technology Transfer and Industry Collaboration</td>
<td>This project supports technical participation in industry collaboration efforts to identify cyber security and privacy issues and requirements for the smart grid, informing members and bringing the utility perspective to the efforts.</td>
</tr>
</tbody>
</table>
P183.001 Mapping the Smart Grid Cyber Security and Privacy Activities Landscape (072128)

Key Research Question

Cyber-physical security and data privacy have become critical priorities for utilities over the past several decades. Many federal agencies, such as the Department of Energy (DOE), the Department of Homeland Security, the Department of Defense, state organizations, and various industry and academic organizations are currently leading and executing cyber security and privacy activities, research, and working groups for the smart grid. Without an overall map of these various activities, the efforts may be redundant or there may be significant gaps in research areas. Many asset owners and operators are currently modernizing their grid systems, with matching funding from DOE under the American Recovery and Reinvestment Act and other grant programs. In addition, the National Institute of Standards and Technology (NIST), as required in the Energy Independence and Security Act, developed an interoperability framework for the smart grid.

Approach

There are many initiatives that are researching and assessing the cyber security requirements of the existing electric grid and the smart grid. The purpose is to provide information to the utilities and to identify potential gaps and conflicts in the various activities.

This project will provide ongoing updates on the status of research and development activities, federal and state policy and regulatory proposals, standards and guidance documents development, key personnel, and organizations that are funding and/or executing smart grid cyber security and privacy activities.

Impact

This project may help asset owners and operators achieve the following:
- Be knowledgeable about the status of various research programs and standards and guidance development efforts
- Gain an understanding of the cyber security and privacy activities currently being undertaken by industry and government groups

How to Apply Results

The information may be used by asset owners and operators to do the following:
- Identify specific activities that are important to the organization
- Select applicable committees and working groups
- Identify gaps in current cyber security and privacy activities
- Reduce the risk of redundancy in research programs

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyber Security and Privacy Landscape Mapping Release 1: This product will be available online for all members to access. The online information will be updated regularly as new activities are identified.</td>
<td>04/02/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Cyber Security and Privacy Landscape Mapping Release 2: This product will be available online for all members to access. The online information will be updated regularly as new activities are identified.</td>
<td>07/02/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Cyber Security and Privacy Landscape Mapping Release 3: This product will be available online for all members to access. The online information will be updated regularly as new activities are identified.</td>
<td>10/01/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
P183.002 Cyber Security and Privacy Technology Transfer and Industry Collaboration (072130)

Key Research Question
With increased attention focused on securing the electric sector, numerous industry groups and public-private partnerships have been created to develop new security requirements and technologies. Additionally, the working groups of organizations such as the North American Electric Reliability Corporation (NERC) and the National Institute of Standards and Technology (NIST) will continue to have a direct impact on the operations of utilities.

While these groups are addressing specific needs in the industry, there is often a lack of availability of utility staff to support all of these efforts. This lack of availability can lead to two key issues. First, utilities are less aware of changes that might impact the industry. Second, the work products being generated may lack the perspective of the utilities.

Approach
This project will support active participation and contribution to collaborative efforts and interest groups such as the following:
- Utilisec
- NIST Smart Grid Interoperability Panel (SGIP) Cyber Security Working Group (CSWG)
- NIST SGIP Design Principles Group
- NAESB Privacy Task Group
- NERC CIP Guideline Working Group
- NERC Cyber Attack Task Force
- Department of Homeland Security Industrial Control Systems Joint Working Group (ICSJWG)

Impact
This project may help members benefit from cyber security and privacy collaborative efforts in these ways:
- Reduce the time necessary to track industry efforts by using a single report for updates
- Reduce the risk that key activities are unnoticed
- Increase the usability of working group products
- Increase the effectiveness of security requirements and solutions that are developed

How to Apply Results
The reports developed from this project may provide a single reference point for members to track the detailed efforts of several industry groups. This project also may increase the relevance and utility of the security reports, controls, and technologies that are being developed.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarter 1 Industry Collaborative Report: Quarterly update on the activities of the industry and government working groups</td>
<td>04/02/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
PS183B Security Technology for T&D Systems (072136)

Project Set Description
This project set intends to address several security challenges facing transmission and distribution (T&D) systems, such as reducing the security risk of legacy systems, assessing substation security solutions, understanding the risk associated with cyber-physical attacks, and securely integrating new power sources such as distributed energy resources.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P183.003</td>
<td>Security Strategies and Solutions for Legacy Systems</td>
<td>This task intends to focus on mitigating the cyber security risks of legacy systems by creating cyber security mitigation strategies and transition strategies for legacy systems.</td>
</tr>
<tr>
<td>P183.004</td>
<td>Network Security Management for Transmission Systems</td>
<td>To develop a security management architecture for WAMPC, ICCP, and substation automation so that the NOC, substations, EMS, and field equipment that support these functions have a consistent set of information security objects in place that are based on an open-standards-based taxonomy.</td>
</tr>
<tr>
<td>P183.005</td>
<td>Risk Management for Cyber-Physical Incidents</td>
<td>This project may provide asset owners and operators with tools and strategies for assessing their smart grid systems.</td>
</tr>
<tr>
<td>P183.006</td>
<td>Assessment of Substation Security Solutions</td>
<td>This project intends to document the current state and transition approaches of various utilities to implementing a secure remote access solution and to assess issues associated with the implementation strategy.</td>
</tr>
<tr>
<td>P183.007</td>
<td>Security Architectures for Distributed Energy Resources</td>
<td>The project will develop security architectures for DER integration into the grid and provide implementation guidelines to meet the security requirements derived from the use case analysis.</td>
</tr>
</tbody>
</table>

P183.003 Security Strategies and Solutions for Legacy Systems (072131)

Key Research Question
Legacy systems continue to pose a security challenge for utilities. Supporting requirements such as integrity, confidentiality, and authentication can be extremely difficult when confronted with the constraints of limited communications bandwidths, lower computation capacity, and legacy protocols. System availability is of primary concern in power control systems and must be taken into account when developing security mitigation strategies. Additionally, vendor design choices such as hard-coding passwords into software also pose security risks.
Given the impracticality of replacing these systems, guidance is required to mitigate the cyber security risk posed by legacy systems. This project will focus on mitigating the cyber security risk of legacy systems by creating transition strategies, cyber security controls, and procedures for legacy systems.

**Approach**

The project will focus on targeting three categories of legacy systems that are selected and prioritized by the project advisors. Once the systems are identified, the project will accomplish the following:

- Develop practical and implementable solutions for existing systems
- Develop guidelines for implementing the solutions
- Provide objective estimates for the resources that will be needed to effectively implement the solutions

**Impact**

This project may help members by mitigating the security risk to legacy systems in the following ways:

- Developing security technology options that account for system constraints
- Creating an understanding of how to implement the recommended security controls
- Allowing utilities to prioritize legacy system security projects based on the resources necessary to implement the solutions

**How to Apply Results**

The cyber security mitigation strategies developed through this project can provide effective and implementable solutions for securing legacy systems. The estimates for implementing the solutions can be used as an input to the member's internal project selection process.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Legacy System Mitigation Report 1</strong>: For the first system selected, this report will provide the results of the risk assessment, risk mitigation solutions, guidelines for implementation, and estimates of technical resources required.</td>
<td>07/02/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Legacy System Mitigation Report 2</strong>: For the second system selected, this report will provide the results of the risk assessment, risk mitigation solutions, guidelines for implementation, and estimates of technical resources required.</td>
<td>10/01/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Legacy System Mitigation Report 3</strong>: For the third system selected, this report will provide the results of the risk assessment, risk mitigation solutions, guidelines for implementation, and estimates of technical resources required.</td>
<td>12/14/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

**P183.004 Network Security Management for Transmission Systems (072132)**

**Key Research Question**

With the rapidly increasing integration of renewable energy sources at the transmission substation level and the greater decision-making capability being pushed down to transmission substation systems to enable voluntary islanding to avoid cascading failures of the electric grid, the cyber security posture of substation automation infrastructure is becoming mission critical.

The use of open standards-based information communication technologies (ICT) to support the inter-control center protocol (ICCP) between network operations centers (NOC) and between the NOC and certain field equipment is introducing new vulnerabilities and threat vectors that can potentially exploit these vulnerabilities.

Wide area monitoring, protection and control (WAMPC) is becoming a critical application for transmission systems to regulate the voltage and phase across the grid for increased reliability and energy efficiency.
Synchrophasors are used on the grid to support the WAMPC function. Securing the WAMPC function over a geographically distributed network against malicious attacks from multiple sources, systemic faults, and natural-disaster-led outages is becoming critical to overall grid reliability and resiliency.

The objective of this project is to develop a security management architecture for WAMPC, ICCP, and substation automation so that the NOC, substations, Energy Management Systems (EMS) and field equipment that support these functions have a consistent set of information security objects in place that are based on an open-standards-based taxonomy.

**Approach**

The project will start with a review of existing security management technologies to determine relevance to transmission system security. The International Electrotechnical Commission (IEC) 62351-7-420 standard will be analyzed to determine which new network security objects are needed for managing transmission system security. Finally, a taxonomy of transmission information security objects will be developed and introduced to the IEC 62351-7-420 Working Group for ratification. In future years the project will introduce this taxonomy to product vendors in this space to incorporate in their transmission information system security tools for an open-standards-based approach to securing the applications and communication protocols that operate in the NOC, substations, PMUs, and other field equipment.

**Impact**

1) Vendor agnostic measure of transmission security posture, 2) Greater security operational awareness for asset owners and operators on transmission systems, 3) Evolution of network security management tools in the industry focused on transmission systems

**How to Apply Results**

The Transmission Information Security Object developed in this project for transmission system security management has to be ratified by IEC 62351-7-420 and product vendors have to test to determine the technological viability. Asset owners and operators can test these in demonstration projects in their service territories before commercial deployment.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td><strong>Object Model Description for Transmission System Security Management:</strong> Development of a security management object model for transmission systems</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

**P183.005 Risk Management for Cyber-Physical Incidents (072133)**

**Key Research Question**

A coordinated cyber-physical attack involves using both cyber and physical means to attack a target. For example, a cyber attack could disable a security system that would allow a physical attack to occur. These coordinated types of attacks will typically be executed by nation-states and terrorists. The smart grid, with the increased use of digital devices, will be more vulnerable to coordinated cyber-physical attacks than the current electric grid. Assessing the impact of coordinated cyber-physical attacks will require a risk-based approach. This task will focus on assessing the attack/failure scenarios that were developed in 2011 and the development of risk assessment strategies and cyber security mitigation strategies for the smart grid. These strategies are part of an overall risk management process for the smart grid.
Approach
This project will build upon the work that was completed in 2011 in the development of attack/failure scenarios and develop scenarios that focus on coordinated cyber-physical attacks. These new scenarios will include the threats and vulnerabilities that may be exploited by a well-financed and motivated nation-state. Next, mitigation and risk assessment strategies will be developed for each coordinated cyber-physical attack scenario. The risk assessment strategies will provide the asset owners and operators guidelines for determining the impact of such an attack.

Impact
- Provide coordinated cyber-physical attack scenarios that can be used by organizations as they assess their smart grid systems and select cyber security and physical security countermeasures
- Provide tools that asset owners and operators can use

How to Apply Results
The products from this project may be used by asset owners and operators as they define and implement an overall cyber security strategy for their smart grid systems. An overall cyber security strategy includes a risk management process that includes a risk assessment process and a risk mitigation strategy. Each component of the strategy may be tailored to specific systems. Most organizations have an overall cyber security strategy and risk management process, but it is typically focused on information technology (IT) systems and not control systems. There are significant differences between the two types of systems.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td>Draft Risk Assessment Processes: Guidance for developing a risk assessment process for cyber-physical attacks</td>
<td>12/14/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Draft Risk Mitigation Strategies: Guidance for developing risk mitigation strategies for cyber-physical attacks</td>
<td>12/14/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

Future Year Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
</table>

P183.006 Assessment of Substation Security Solutions (072134)

Key Research Question
Leveraging remote access capabilities on substations can provide new opportunities for data integration solutions including fault location, data archiving and PQ monitoring. However, balancing cyber security and security compliance requirements with the need for remote substation access to an increasing number of IEDs can be very difficult. This delicate balance can be achieved through proper preparation, procedure implementation, and organizational support. The use of commercially available software packages also can ease the transition and implementation efforts. Guidance materials and reference standards relating to substation security, such as NISTIR 7628 and IEC 62351, should also be considered when developing remote access security strategies.
**Approach**

This project will document the current state and actual transition approaches of various utilities to implementing a secure remote access solution and assess issues associated with the implementation strategy. EPRI may also examine the various approaches proposed or being implemented by utilities deploying secure remote access solutions and assess the pros and cons. Lessons learned may be documented and communicated. This project may also include use of EPRI’s Smart Grid Substation Laboratory as appropriate.

**Impact**

This project may have the following impacts:

- Better understanding of the pros and cons of various remote access implementation methods and the challenges associated with each
- Assistance with the planning, designing, development, and implementation of a secure remote access strategy for their companies

**How to Apply Results**

Members may be able to apply the knowledge gained from the project products to designing and effectively implementing a secure remote substation access solution.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td>Substation Security and Remote Access Implementation Strategies: Current state of security for remote access solutions, approaches for securing remote access, and lessons learned from prior implementation efforts.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

**P183.007 Security Architectures for Distributed Energy Resources (072135)**

**Key Research Question**

Distributed energy resources such as solar, wind, and electric storage are being widely deployed at the transmission, distribution, and customer premises levels. Each of these implementations creates the possibility of new threat vectors as multiple entities are working with the electric utilities to deliver these services. To mitigate the risks associated with this heterogeneous network of autonomously administered infrastructures, security architectures need to be developed that provide "defense in depth" to thwart attacks from hackers, criminal rings, and rogue states and provide resiliency against system outages due to natural disasters. This project will develop security architectures so that DER can be securely integrated into the grid.

**Approach**

The project intends to analyze security-related use cases for DER and identify vulnerabilities and threats. A risk assessment may be performed to develop a set of security requirements for integrating distributed energy resources (DER) into the grid at the transmission, distribution, and customer premises level. A security architecture may be created to meet the cyber security requirements for DER. A set of implementation guidelines may be established to help the asset owner and operator know how to interconnect the DER with the grid and maintain a "defense in depth" security posture.

**Impact**

1) Guidelines for providers of DER of what standard security controls have to be in place to interconnect with the electric grid at various points, and 2) Well-defined security architectures for DER integration to enable utilities and product vendors to agree on standard implementation strategies for increased security and reliability.
How to Apply Results

Asset owners and operators and DER service provider will use the results to improve the security of deployment of DER technologies in the field using standard implementation guidelines, best practices, and criteria for measuring the security posture.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>Security Architecture for DER Integration into the Electric Grid: The Technical Update will provide a security architecture for DER integration into the grid and list a set of implementation guidelines to meet the security requirements derived from the use case analysis.</td>
<td>12/14/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

PS183C Security and Privacy for End Use Technology (072141)

Project Set Description

End-user technology continues to evolve at a rapid pace. This project set intends to focus on issues related to scalability of technologies such as key management, creation of security testing tools and techniques, and technical solutions to support privacy of end-user data.

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P183.008</td>
<td>Technology Solutions for Supporting Privacy of End-User Data</td>
<td>This project will identify and evaluate the technology required to store, aggregate, analyze, and protect energy usage data (and other personally identifiable information).</td>
</tr>
<tr>
<td>P183.009</td>
<td>Standardized Security Objects for AMI</td>
<td>This project helps increase the interoperability of AMI security objects, allowing other vendors to create solutions for AMI incident detection and situational awareness.</td>
</tr>
<tr>
<td>P183.010</td>
<td>Tools and Techniques for Security Testing of End-User Devices</td>
<td>This project develops security testing tools and techniques to effectively test the security of a variety of end-user devices.</td>
</tr>
<tr>
<td>P183.011</td>
<td>Cryptography and Key Management</td>
<td>This project focuses on a scalable CKMS for the smart grid systems that will be deployed throughout the United States.</td>
</tr>
</tbody>
</table>

P183.008 Technology Solutions for Supporting Privacy of End-User Data (072137)

Key Research Question

Communications technology enables the bidirectional flow of information throughout the smart grid. The granularity, or depth and breadth of detail, captured in the information collected and the interconnections created by the smart grid are factors that contribute to the privacy concerns about the smart grid. Current privacy laws may not explicitly reference the smart grid or associated unique smart grid data items, and existing U.S. state-level smart grid and electricity delivery regulations may not explicitly reference privacy protections. Also, more data, and more detailed data, may be collected, generated, and aggregated through smart grid operations than previously collected through monthly meter readings and distribution grid operations.

Approach

This project will build upon the work that is being done by the Smart Grid Interoperability Panel (SGIP) Cyber Security Working Group (CSWG), the American Bar Association Privacy Working Group, and the North American Electric Standards Board (NAESB) Data Privacy Task Force, and the National Institute of Standards...
and Technology (NIST) priority action plan on standardized energy usage data format. These programs are developing privacy use cases and recommending privacy practices. The technology required to store, aggregate, analyze, and protect energy usage data (and other personally identifiable information) needs to be identified and evaluated. Some of the technology solutions will be deployed in the advanced metering infrastructure (AMI), which has bandwidth and processing constraints.

**Impact**

Currently, technology has focused on cyber and physical security requirements to address threats and vulnerabilities. Some of the technology also may be used to address privacy requirements. This project will assess technology to achieve the following:

- Provide an assessment of technology that may be used in the storage, aggregation, and/or analysis of privacy-protected energy usage data
- Provide proposed alternative logical architectures for the privacy protection of energy usage data
- Include in the logical architectures the sharing of energy usage data with third-party service providers, such as Google and Microsoft, that have home energy management systems

**How to Apply Results**

The products from this project may be used by asset owners and operators as they configure their smart grid systems and deploy AMI infrastructures and potentially interact with third-party vendors. The technology also is needed to ensure that requested privacy data is available for forensic analysis and law enforcement needs.

### 2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assessment of Technology Used to Protect the Privacy of Energy Usage Data:</strong> Initial release of the technology assessment report that asset owners and operators may use as they configure and deploy smart grid components and systems that contain privacy-protected energy usage data</td>
<td>09/14/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

### Future Year Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td><strong>Final Report on the Assessment of Technology Used to Protect the Privacy of Energy Usage Data:</strong> Final release of the technology assessment report that asset owners and operators may use as they configure and deploy smart grid components and systems that contain privacy-protected energy usage data</td>
<td>03/29/13</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>

**P183.009 Standardized Security Objects for AMI (072138)**

**Key Research Question**

With the widespread deployment of large-scale advanced metering infrastructure (AMI) systems, utilities must confront the task of responding to alerts and alarms that are generated by the meters. However, AMI systems are usually operated in a silo and are not easily integrated into intrusion detection systems. This is due to the fact that AMI vendors do not use standard data objects for representing the alerts and alarms that are generated by the meters.

The objective of this project is to develop standard security objects for AMI systems. This would allow third-party vendors to develop security applications to use and display the alerts generated by the meters to provide better situational awareness to the AMI operators.
Approach
This project is expected to build on AMI intrusion detection work that was performed in the PDU Cyber Security and Privacy Initiative. In the initiative, EPRI coordinated with major AMI vendors to identify specific alerts and alarms for which standard security objects should be developed. This project intends to continue that work by developing a consensus among the vendors for how each of the alerts and alarms should be represented. Third-party security application vendors may also be included to accelerate the development of AMI IDS systems. Finally, the interoperability of the AMI vendors’ implementations is intended to be verified in a laboratory environment.

Impact
- Allow third-party vendors that specialize in intrusion detection systems to more effectively support AMI monitoring
- Allow utilities to more efficiently integrate multiple meter vendors into their AMI intrusion detection systems
- Create a foundation for integrating AMI security incidents into a unified smart grid monitoring system

How to Apply Results
AMI vendors may adopt the standardized security data objects into a new firmware or system release for their AMI system. Once the update is released, utilities can then choose to upgrade their AMI systems.

2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security Object Specifications for AMI Systems: Well-specified data formats for alerts and alarms for AMI systems</td>
<td>12/14/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

P183.010 Tools and Techniques for Security Testing of End-User Devices (072139)

Key Research Question
The increase in prevalence of end-user devices creates new security concerns for the home area network (HAN). These devices include programmable communicating thermostats (PCT), in-home displays, energy management systems, and electric vehicles. Additionally, the introduction of new, complex standards such as the Smart Energy Profile 2.0 can increase the risk of vulnerabilities through implementation errors. The objective of this project is to develop tools and techniques for performing security testing on end-user devices, increasing the quality and prevalence of testing that is being performed by utilities and vendors.

Approach
This project is expected to focus on developing security testing tools and techniques for end-user devices. This can be done by utilizing commercial-off-the-shelf embedded boards and libraries to develop testing platforms. The testing platform can be programmed to perform a variety of security tests on commercial end-user devices. The types of tests that will be performed may include protocol level tests, denial-of-service and fuzzing attacks at multiple layers of the network stack, data integrity tests, replay attacks, and authentication tests.

Impact
- Providing security tools that utilities can download and use directly in their environments
- Creating a set of standard security testing techniques for the end-user domain
How to Apply Results

Utilities may be able to more efficiently and effectively perform security testing on end-user devices by directly using the tools that are being developed or by contracting third-party penetration testers to apply the testing techniques.

2012 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security Testing Techniques for End-User Devices: Security test plan for penetration testing of end-user devices</td>
<td>12/14/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Security Testing Tool for End-User Devices: Software and firmware developed to implement the security testing techniques</td>
<td>12/14/12</td>
<td>Software</td>
</tr>
<tr>
<td>Documentation for Security Testing Tool</td>
<td>12/14/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>

P183.011 Cryptography and Key Management (072140)

Key Research Question

Cryptography is often used to protect information from unauthorized disclosure, to detect modification, and to authenticate the identities of system users. Cryptography is particularly useful when data transmission or authentication occurs over communications networks for which physical means of protection are often cost-prohibitive or even impossible to implement. Cryptography also provides a layer of protection for stored data. Cryptographic techniques use cryptographic keys that are managed and protected throughout their life cycles by a cryptographic key management system (CKMS). The focus of a CKMS is on the generation, distribution, and storage of cryptographic keys. For the smart grid, there will be millions of meters that contain cryptographic keys used for authentication, integrity of software and firmware updates, and confidentiality of privacy data. Each meter may contain several cryptographic keys. Also, cryptographic keys will be used to ensure the confidentiality of sensitive market data and the integrity of commands sent to control system devices. In total, there will be hundreds of millions (potentially billions) of cryptographic keys. Current technology to manage all these keys does not scale to this new scope.

Approach

This project will focus on the following key management functions: generation, distribution, storage, use, revocation, and destruction of cryptographic keys and bound metadata used in the smart grid. This project will build on the work done by the Smart Grid Interoperability Panel (SGIP) Cyber Security Working Group (CSWG) Design Principles Group (DPG) and the Sypris DOE funded grant. The DPG is expanding upon the content of the NIST Interagency Report 7628, Guidelines for Smart Grid Cyber Security, and providing more detailed guidance on cryptographic key management. Sypris is researching how to scale key management for the smart grid and developing models to assess scalability. This project will address, for example, the following:

- The required high-level functions of the CKMS
- The performance characteristics of the CKMS
- Scaling the CKMS to exceed the peak performance characteristics, if necessary
- Key distribution and revocation
- Selection of commercially available off-the-shelf (COTS) products to be used in the CKMS design
- Configuring the COTS products to address smart grid CKMS requirements
- The system roles supported by the smart grid CKMS
Impact

Enable asset owners and operators to accomplish the following:

- Specify the cyber security requirements of the CKMS for the smart grid system
- Assess alternative CKMS technologies to meet their specific requirements
- Design and configure the CKMS systems

How to Apply Results

The guidelines and tools provided can be used by asset owners and operators as they specify, design, and implement a smart grid CKMS.

2012 Products

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<td>Cryptographic Key Management System Design Assessment and Guidance: Asset owners and operators may use the guidance document in designing and configuring a CKMS.</td>
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Supplemental Projects

Secure Integration of AMI into Substation Networks (072142)

Background, Objectives, and New Learnings

Asset owners in the electric utility industry are testing the feasibility of using the advanced metering infrastructure (AMI) communication network to cost-effectively connect field equipment in geographically dispersed distribution systems to the substation to control the 2-way flow of electricity between the grid and the customer premises. Additionally, the energy usage, voltage, and phase data from smart meters could be used by the next generation of supervisory control and data acquisition (SCADA) applications to do better volt/var optimization and reduce line losses. The integration of AMI into the substation requires a thorough risk assessment to determine the vulnerabilities and new threat vectors that could arise from linking infrastructure that is linked with customer premises to the power systems control network that connects to a substation. The objective of this project is to understand how to apply this risk assessment result to the design of a secure method of integrating AMI into substation for advanced grid control strategies that may lead to lower energy losses.

Project Approach and Summary

The project will analyze use cases for distribution grid management and identify the vulnerabilities and threat vectors associated with integrating the AMI to substations. The project will provide mitigation strategies that asset owners and operators can implement to reduce the risk associated with integrating AMI to substations. The project also will develop implementation guidelines for securely integrating AMI to substations and define criteria for measuring the security posture of the proposed architecture. Future years will be focused on working with product vendors and the utilities to test the architecture and validate the underlying assumptions for security and reliability.

Benefits

The results from this project may lead to a more secure power delivery system that can be operated at a lower cost, helping utilities as well as the public. This can be accomplished by utilizing the existing communications infrastructure more efficiently and securely for both substation and customer equipment and meters.

The expected results may include:

- Low-cost communication network for distributed grid management that is secure,
- Cost-effective control infrastructure that can handle large penetration of intermittent sources of electricity such as solar and wind at the distribution and substation level, and
- Delivering end-use load data to next generation SCADA applications to reduce line losses
Nuclear

Developing safe, reliable, economical, and environmentally responsible technologies that enable the long-term operation of existing nuclear plants and the deployment of advanced nuclear power plants

Advanced Nuclear Technology
Chemistry, Low-Level Waste, and Radiation Management
Equipment Reliability
Fuel Reliability
Long-Term Operations
Materials Degradation/Aging
Nondestructive Evaluation and Material Characterization
Risk and Safety Management
Used Fuel and High-Level Waste Management
Primary Systems Corrosion Research

Program Overview

Program Description

Materials degradation problems due to environmentally assisted cracking in nuclear power plants have cost the nuclear industry at least $10 billion in the last 30 years because of forced and extended outages, increased inspection requirements, and component repairs and replacements. Inadequate understanding of the processes that lead to stress corrosion cracking has hampered the development of reliable predictive models and cost-effective mitigation technologies. As the majority of existing plants move toward the extended operation period, understanding of materials-aging phenomena becomes critically important in developing a sound management strategy to ensure the long-term reliability of primary system components.

The Primary Systems Corrosion Research Program improves the useful life of primary system components in boiling water and pressurized water reactors through a deeper understanding of the crack initiation and early propagation processes involved in stress corrosion cracking and irradiation-assisted stress corrosion cracking. Extensive global collaboration ensures that research findings reflect a wide range of nuclear technologies, operating conditions, and service environments.

Research Value

The Primary Systems Corrosion Research Program enhances nuclear industry understanding of the early stages of damage to irradiated materials used in boiling water and pressurized water reactor internals. Research results lead to improved predictive models and potential countermeasures that can significantly extend the useful life of plant components. Primary Systems Corrosion Research Program participants gain access to the following:

- Strategic roadmaps outlining research gaps confronting irradiated materials testing for initiation and crack growth data in boiling and pressurized water reactors
- Mechanistically based predictive models of degradation and mitigation techniques to manage material corrosion issues in reactor internals
- Better understanding of early stages of stress corrosion cracking in nickel-base alloys and stainless steels
- Methods to mitigate damage and significantly extend component life
- Knowledge sharing through global collaboration with utilities, vendors, regulators, and research organizations

Approach

The Primary Systems Corrosion Research Program conducts and coordinates experimental and theoretical studies to advance the mechanistic understanding and predictive modeling of crack initiation and early crack propagation. Fundamental understanding of the early stages of stress corrosion cracking and irradiation-assisted cracking in light water reactor materials can lead to reliable models for predicting damage progression and more effective mitigation technologies. The program applies additional resources through collaboration with EPRI's Technology Innovation program, the U.S. Department of Energy, and international organizations.

Program results are transferred to the appropriate Electric Power Research Institute (EPRI) Issues Programs (Boiling Water Reactor Vessels and Internals Project, Materials Reliability Program, and Steam Generator Management Program) for application via inspection and evaluation guidelines and other mechanisms.
Research activities in the Primary Systems Corrosion Research Program include the following:

- Develop improved material characterization and mitigation technologies to manage materials degradation and corrosion-related issues
- Maintain and update the Materials Degradation Matrix and the Materials Handbook
- Address the knowledge gaps identified in the Materials Degradation Matrix and Issue Management Tables associated with near-term and long-term operation reliability
- Maintain and update the Materials Information Portal, which integrates with and links to the Materials Degradation Matrix, Issue Management Tables, Materials Handbook, issue resolution roadmaps, and materials research project information
- Participate in global research consortia to better understand the role of key parameters on irradiation-assisted stress corrosion cracking of reactor materials and to develop improved materials
- Conduct crack growth rate testing of irradiated alloy materials to evaluate the effect of material composition, fluence, flux, stress intensity, and environment
- Compile and screen crack growth data on irradiated materials and use the data to develop appropriate crack growth models for boiling water reactor (BWR) and pressurized water reactor (PWR) internals in collaboration with other EPRI programs
- Develop test methods to study stress corrosion cracking initiation, coalescence, and growth in nickel-base alloys in pressurized water reactors

Accomplishments

EPRI's Primary Systems Corrosion Research Program supports nuclear power industry efforts to identify and mitigate early stages of materials degradation to extend component life.

- Evaluated the low-temperature crack propagation susceptibility of thermally aged cast austenitic stainless steel, revealing a significant decrease in fracture toughness in PWR shutdown chemistry.
- Assessed the effects of silicon on the electrochemical behavior and environmentally assisted cracking of non-irradiated stainless steels. Silicon enrichment is observed in the grain boundaries of irradiated materials. The results of this study indicate that the use of non-irradiated bulk analog materials to simulate the cracking response of irradiated materials must be approached with caution.
- Updated the Materials Degradation Matrix to address long-term operation up to 80 years. These results provide input to development of Issue Management Tables for BWRs and PWRs.
- Created an on-line Materials Information Portal to provide easy and integrated access to the Issue Management Tables, Materials Degradation Matrices, and supporting technical reports that underlie EPRI's materials research activities.
- Completed final review of the Cooperative Irradiation-Assisted Stress Corrosion Cracking Research Program, summarizing more than 15 years of research into the mechanisms involved in irradiation-assisted stress corrosion cracking, the development of predictive models, and evaluation of potential countermeasures.
- Updated the Materials Handbook for Nuclear Plant Pressure Boundary Applications, which provides accurate structural materials properties and performance data that inform decisions regarding the adequacy of materials for nuclear power applications.
- Quantified the effect of key parameters on crack growth rates of fast-reactor-irradiated stainless steels in boiling water reactor and pressurized water reactor environments.
- Demonstrated the strong correlation between the degree of localized deformation and irradiation-assisted stress corrosion cracking in austenitic alloys.
Current Year Activities

Primary Systems Corrosion Research Program research and development for 2011 will focus on improving the understanding of corrosion mechanisms in nuclear materials, leading to more effective management and mitigation strategies for extended operation life of existing plants and better materials selection for new plants. Specific efforts will include the following:

- Address emerging issues associated with extended operation life beyond 60 years, as identified in the revised Materials Degradation Matrix
- Investigate susceptibility of neutron-irradiated stainless steels to irradiation-assisted stress corrosion cracking and identify the controlling mechanisms
- Study the mechanisms of stress corrosion cracking initiation and crack coalescence in nickel alloys in PWR primary water
- Study the effect of strain localization on intergranular stress corrosion cracking in stainless steels and nickel alloys
- Investigate the effect of light water reactor environments on fracture resistance of irradiated stainless steels and nickel-base weld metals
- Use state-of-art nanoscale characterization techniques (atom probe tomography, in-situ-Raman spectroscopy and synchrotron-X-rays) to investigate the mechanisms of stress corrosion cracking and irradiation-assisted stress corrosion cracking in light water reactor materials
- Investigate plastic strains in the heat-affected zone of Alloy 690 welds and their role in stress corrosion cracking
- Explore new experiment methodology in studying stress corrosion cracking initiation in Alloys 690/52/152

Estimated 2012 Program Funding

$3.9 million

Program Manager

Rajeshwar Pathania, 650-855-8762, rpathani@epri.com

Summary of Projects

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BWR & PWR Irradiated Materials Testing and Degradation Models (Roadmap) (QA)

Key Research Question

The performance of BWR and PWR reactor internals are affected by several irradiation-based degradation mechanisms: irradiation–assisted stress corrosion cracking (IASCC), irradiation embrittlement (reduction in ductility and fracture toughness), creep, stress relaxation and void swelling. Limited understanding of the factors affecting these degradation modes (such as dose, dose rate, stress intensity factors, effects of specimen size and orientation, solute additions, temperature and environmental conditions) could impact decisions related to extended operation up to 80 years. Knowledge gaps exist, for example, on the effects of high fluence on degradation of base metal, welds and heat-affected zones in BWR and PWR environments. Experimental
information also is lacking that could lead to the development of more robust, fundamentally based models and radiation resistant materials.

**Approach**

Long-term irradiation effects will be characterized by testing materials removed from retired plants such as the Zorita PWR in Spain and the Bärseback BWR in Sweden. The Zorita plant was operated for 38 years (26 Effective Full Power Years) and the highest fluence on the reactor vessel internals is approximately 58 displacements per atom (dpa). Some of the material removed from Zorita will be re-irradiated in a research reactor to achieve fluence values expected in 60 to 80 years.

EPRI will continue its participation in the international collaborative program on irradiated materials testing at the Halden Reactor. EPRI also will collaborate with the Idaho National Laboratory to conduct irradiations and post-irradiation testing of BWR materials at the Advanced Test Reactor.

An EPRI expert panel will compile and screen crack growth data on irradiated materials from EPRI-sponsored studies, international collaborative programs, and technical literature and develop more robust models to predict residual lifetimes of irradiated internals in BWRs and PWRs.

**Impact**

**Asset management**: Improved understanding of irradiation effects can significantly affect decisions related to repairs, replacements, and even overall unit life. Improved understanding of irradiation-induced degradation based on additional data and more accurate models can be used to make sound repair or replacement decisions and avoid unanticipated outages associated with cracking of internals.

**Regulatory and Industry Commitments**: Regulatory commitments during license renewal typically require plants to implement an aging management program that follows industry guidance. Such programs are based on the technical foundation established in the inspection and evaluation guidelines developed and maintained through EPRI research. This work also supports industry commitments through efforts such as the NEI-03-08 Materials Initiative.

**How to Apply Results**

The improved data and degradation models developed under this program will be incorporated into industry guidance for managing internals degradation in BWRs and PWRs. The goal is to provide all necessary data and models to support light water reactor operation through 80 years. Examples include the following:

- Improved crack growth rate models and disposition curves for BWR (e.g. BWRVIP-99-A) and PWR internals based on an enhanced database and input from an expert panel. These models will support utility decisions on inspection frequency, repair, and replacements.
- Improved irradiation-assisted stress corrosion cracking (IASCC) initiation models for PWR internals based on data from materials removed from the retired PWR plants such as Zorita. The materials include stainless steel base metal, welds, and heat-affected zones.
- Improved fracture toughness models for BWR (e.g. BWRVIP-100, Rev. 1) and PWR internals to support structural margin and integrity analyses.
- Improved void swelling model for PWRs based on results from the Gondole project.
- Radiation-resistant materials for future replacements of internals or for new plants.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.
Steam Generator Management (QA)

Program Overview

Program Description
Many factors affect materials degradation in steam generators, including water chemistry, inspection limitations, material performance issues, and the presence of foreign objects. Greater understanding of these factors and their integrated impacts will lead to more effective tools to predict the potential for degradation and more effective inspection and mitigation techniques to identify and address degradation.

The Steam Generator Management Program (SGMP) conducts research to ensure the safe, reliable, and economic operation of steam generators in pressurized water reactor plants. Research activities target identification and mitigation of various forms of steam generator degradation, foreign object assessments, optimized operation of replacement steam generators, water chemistry, in-service inspections, and tube integrity.

Research Value
The Steam Generator Management Program drives greater consistency in managing steam generator issues across the nuclear fleet. The program develops guidance for existing issues such as degradation in steam generators with original Alloy 600 MA tubes, as well as emerging issues such as managing degradation in steam generators with the more corrosion-resistant Alloys 600 TT, Alloy 690 TT, and Alloy 800 tubes. SGMP participants gain access to the following:

- Strategic roadmaps outlining research gaps confronting key issues—such as foreign object management and steam generator life management—and the collaborative actions needed to address these gaps
- Guideline documents that reduce the potential for steam generator tube ruptures and forced leakage outages, which can cost an estimated $5 to $20 million per event
- Better tools for integrity assessments, reducing unnecessary examinations that can cost an estimated $1 to $2 million per plant
- Chemistry controls that can delay the onset of corrosion and mitigate steam generator fouling
- A database of worldwide steam generator information related to degradation, used to assist utilities with decisions on steam generator operation and maintenance

Approach
The Steam Generator Management Program applies an integrated approach for managing steam generator materials degradation in pressurized water reactors. The program develops guidance through improved understanding of how multiple variables impact steam generator operation and maintenance, including thermal hydraulics, water chemistry, tubing materials, inspection techniques, and tube-plugging/repair criteria.

SGMP closely collaborates with other EPRI programs, including Materials Reliability, Nondestructive Evaluation, and Chemistry, to ensure appropriate technologies and technical guidance are effectively integrated into research activities.

There are both base and supplemental components of the Steam Generator Management Program. The base portion encompasses nondestructive evaluation (NDE) research and development (R&D), water chemistry, materials performance/thermal hydraulics, and the Steam Generator Degradation Database.

- Nondestructive Evaluation R&D: This project develops tools such as software algorithms, improved inspection techniques, and database libraries to enhance the accuracy and efficiency of steam generator inspections. Improved flaw detection and flaw sizing accuracy capabilities, for example, could better inform decisions regarding operating intervals between inspections.
• **Water Chemistry**: This project develops guidelines, chemistry technologies, and predictive models to minimize steam generator tube corrosion and fouling, and to optimize chemistry for safe, reliable, and long-term steam generator operation. Advanced technology developments are incorporated into application sourcebooks to inform water chemistry control actions, including the use of improved amines, dispersants, molar ratio control, and intergranular stress corrosion cracking inhibition.

• **Materials Performance and Thermal Hydraulics**: Foreign objects and tube wear can threaten safe and reliable steam generator operation. This project conducts experiments and develops computational simulations that more accurately estimate foreign object movements and tube wear rates from steam generator foreign objects. Prediction tools and on-line measurement techniques also are needed to manage issues resulting from buildup on tube support plates. Finally, corrosion studies can help determine the effect of various steam generator environments on tube degradation rates.

• **Steam Generator Degradation Database**: This project maintains a web-accessible database of steam generator information. This database contributes to the safe and reliable operation of steam generators by providing data to inform decisions regarding inspection scope, tube repair activities, and the effectiveness of steam generator corrective actions, such as chemical cleaning.

To address strategic objectives established for each of its programs, the Electric Power Research Institute (EPRI) has developed roadmaps to plan, coordinate, and execute needed research among multiple entities. For the Steam Generator Management Program, roadmaps have been developed to address the technical barriers confronting foreign object detection and characterization and effective steam generator life management. Additional roadmaps will be developed as conditions warrant.

The supplemental portion of the Steam Generator Management Program provides mechanisms for responding to emerging issues and for developing effective monitoring and assessment programs.

• **Supplemental Research and Emerging Issues**: This project enables EPRI to conduct research to address emerging technical, operational, and regulatory issues not anticipated in annual research planning. This project also facilitates research in specific areas that may not be of interest to the broader base program participants. Such research could include additional capabilities for software products, database maintenance for alternate tube repair criteria, and review of newly developed chemical additives.

• **Structural Integrity Assessment and Nondestructive Evaluation Field Support**: This project develops products to ensure steam generator tube integrity through thorough inspections, condition monitoring, and operational assessments. Cornerstone products include the *Steam Generator Examination Guidelines* and its qualification program, the *Steam Generator Integrity Assessment Guidelines*, the *Steam Generator Primary-to-Secondary Leakage Guidelines*, and the *Steam Generator In-Situ Pressure Test Guidelines*.

**Accomplishments**

The Electric Power Research Institute's (EPRI's) Steam Generator Management Program supports nuclear power industry efforts to minimize the potential for steam generator tube ruptures, forced leakage outages, and other steam generator integrity issues. Accomplishments include both technology development and technical support, spanning more cost-effective nondestructive evaluation techniques for steam generators to technical justification for regulatory issues.

• Updated guideline and supporting technical documents implementing the requirements of nuclear industry initiative NEI 97-06, which imposes requirements for a nuclear plant’s steam generator program

• Developed new applications for dispersant use beyond online addition to significantly reduce steam generator fouling: dispersant addition during steam generator wet layup as well as during the long-path recirculation cleanup of the condensate and feedwater systems just prior to plant startup

• Developed software algorithms for automatic eddy current data analysis, demonstrated high levels of performance for detection of steam generator tube degradation, and transferred the technology to NDE organizations for field application.
• Developed eddy current data analysis guidance for detection of various types and sizes of steam generator foreign objects
• Completed an engineering study of divider plate cracking for 40-year plant life.
• Performed an assessment of potential mechanisms for lead transport to steam generator tube crack tips
• Developed a prioritization strategy for managing foreign objects in square pitch and triangular pitch steam generators
• Analyzed the impact of advanced amine use on iron transport, flow accelerated corrosion, and steam generator fouling in pressurized water reactor secondary systems

Current Year Activities
Steam Generator Management Program research and development for 2012 will focus on continued development of dispersant applications; advanced inspection and inspection analysis methods; root causes of steam generator degradation; and guideline revisions related to water chemistry. Specific efforts include the following:

• Update the **Primary-to-Secondary Leak Guidelines**, which define needed requirements and provide guidance in optimizing a plant’s primary-to-secondary leak program
• Update the **In Situ Pressure Test Guidelines**, which define needed requirements and provide guidance in performing pressure tests of degraded steam generator tubes to directly demonstrate tube integrity
• Provide a significant update to the **PWR Dispersant Application Sourcebook**, incorporating significant industry experience and additional application technologies
• Continue development of advanced software algorithms for automated eddy current data analysis for detection of steam generator degradation and foreign objects.
• Update **Generic Predictions**, which includes predicting the future extent of tube degradation in steam generators with Alloy 800NG, Alloy 600TT, and Alloy 690TT tubes
• Continue research to understand the safety significance of divider plate crack propagation during extended periods of performance.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Estimated 2012 Program Funding
$7.7 million

Program Manager
James Benson, 704-595-2550, jbenson@epri.com
Summary of Projects

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Steam Generator Foreign Object Management (Roadmap)

Key Research Question

Corrosion was the dominant tube degradation mode for steam generators manufactured with Alloy 600MA tubing. Most steam generators with Alloy 600MA tubing have been replaced with steam generators that have more corrosion resistant tubing such as Alloy 600TT, 690TT or 800NG. As a result, corrosion of steam generator tubing is decreasing and other degradation modes are becoming more important.

Foreign objects on the secondary side of steam generators cause tube wear that can challenge tube integrity and can lead to primary-to-secondary leakage and unplanned outages. This is currently the number one cause of steam generator forced outages. Foreign objects include material that is accidentally left in the secondary system during installation or repairs and material from degraded components in the secondary system. Although foreign material exclusion programs are in place at plants to minimize the number of foreign objects in the secondary system, it is not possible to eliminate all foreign objects. As such, a strategy to manage foreign objects and the associated degradation on the secondary side of a steam generator is needed.

Approach

This work is divided into three essential areas. These areas are needed in conjunction with each other to adequately manage the issues and the associated consequences related to foreign objects within steam generators.

Effective Inspection

Existing primary side eddy current techniques for managing foreign objects are limited. The goals of the research are to improve foreign object primary side eddy current detection and sizing capabilities and to develop a secondary-side inspection method that can assess tube damage from a foreign object. The secondary side inspection technique will enable utilities to size wear without accessing the primary side. This will be useful if tube wear is observed from a visual inspection on the secondary side during an outage when primary-side inspections are not conducted or after primary side inspections are complete.

Development of new primary side inspection techniques requires experienced eddy current analysts to propose and test innovative methods to acquire and analyze eddy current data. The eddy current data will be collected in a laboratory with tubes that have tube wear and with parts in locations that are expected in the steam generators. This will be done using several different probe designs. Each successful method will be added to the library of accepted eddy current inspection methods that are used by the inspection vendors.

A promising secondary side sizing technique based on optical depth measurement will be developed and evaluated for its ability to measure tube wear on the secondary side of a steam generator. Upon completion, the technology will be transferred to a vendor for commercialization and then it will be offered as a service to the utilities.
Evaluation
During an outage, many foreign objects can be located in the steam generator. A structured process will enable the steam generator engineer to decide the action needed when foreign objects are detected and assist with the prioritization of foreign object retrieval. EPRI will develop a first-principles-based method to predict potential wear from a foreign object and will qualitatively confirm the results using experimental data. This method will be applied generically to develop a prioritization scheme for removal of foreign objects (size and mass) that are located in a steam generator. Prediction of potential foreign object wear using this methodology will be used for tube integrity assessments.

Foreign Object Handbook
EPRI will maintain and update the Foreign Object Handbook which provides an overall strategy for managing foreign objects. This handbook will capture operational experience, recommended inspection practices, foreign materials exclusion practices, prioritization schemes, and tube wear prediction methods.

Impact
Operational Drivers: In the worst cases, tube degradation from foreign objects can lead to unplanned outages due to primary-to-secondary leakage. From a more practical standpoint, foreign objects and associated tube wear may lead to an unplanned expanded eddy current inspection scope, an unplanned tube plugging campaign, and/or an inability to operate multiple cycles between inspections. In addition, inability to accurately size foreign object wear leads to unnecessary in-situ pressure tests to demonstrate tube integrity. These activities can significantly increase worker radiation exposure, outage costs, and schedule.

Regulatory Drivers: Regulators are concerned that existing eddy current inspection practices may not adequately identify foreign objects or foreign object tube wear indications. Undetected foreign objects or tube indications that are missed or inaccurately sized during inspection may lead to a degraded tube that causes a primary-to-secondary leak.

How to Apply Results
Upon completion of this work, the following can be expected:

- Improved eddy current inspection techniques and new secondary side wear sizing techniques will be integrated into vendor services that are provided to the utilities. These techniques will better identify and size tube wear, and locate foreign objects.
- EPRI’s Foreign Object Handbook (EPRI Product 1014981) will serve as the basis for utilities and steam generator vendors to implement a plant-specific strategy for managing foreign objects. This document will include a method to prioritize the order in which objects should be removed from the steam generator, an industry accepted method to predict tube wear, and a summary of relevant operating experience.
- Utility foreign materials exclusion program managers in conjunction with utility steam generator engineers will maintain a foreign materials exclusion program that is based on EPRI’s Nuclear Maintenance Applications Center: Foreign Material Exclusion (EPRI Product 1016315 and subsequent revisions) and INPO’s Achieving Excellence in Foreign Material Exclusion (INPO 07-008 and subsequent revisions).

NEI 03-08 steam generator guideline documents will be updated by EPRI and implemented by the utilities to address research results and operating experience related to foreign objects.

Steam Generator Life Management (Roadmap)

Key Research Question
Steam generator life-cycle management must balance the implementation of measures to mitigate or repair existing degradation and the application of techniques to reduce the likelihood of future degradation against the associated costs. Recent operating experience demonstrates that current knowledge of relevant degradation
mechanisms and existing mitigation options may be inadequate to accurately project and maximize steam generator life:

- Fatigue failure and primary-to-secondary leaks have occurred in three steam generator tubes caused by significant deposit accumulation on the tube support plates.
- Denting of steam generator tubes at the top of the tubesheet has occurred at seven plants. Denting occurred in as many as 1500 tubes in a single plant and caused stress corrosion cracking and tube repair in three of the plants.
- Stress corrosion cracks are being detected in Alloy 600TT and Alloy 800NG steam generators.
- In plants that have implemented power uprates, deposit accumulation has limited thermal performance.

Approach

The project plan is shown in the flowchart. The primary focus is on strategic planning to maximize steam generator life and optimize steam generator performance. The work is divided into four areas:

Deposit Management
Secondary side water chemistry in conjunction with deposit removal techniques control the deposit accumulation on steam generator tubes and tube support plates.

EPRI will update the *Dispersant Application Sourcebook* to include lessons learned and recommendations from plants using on-line dispersant application. Dispersants suspend corrosion products in the steam generator bulk water and repel corrosion products away from the tubes/deposits, thereby preventing corrosion products from adhering to the tubes/deposits. Ongoing research and field trials are exploring the possibility of using dispersants during outages (steam generator wet lay up) to remove deposits from steam generator tubes and during startup (long-path re-circulation) to prevent corrosion products from reaching steam generators.

Crystal habit modifiers can be used to control or tailor deposit properties. Results from preliminary experiments look promising. If specific amines or their degradation products are found to significantly affect the crystal habit of corrosion product particles, this would allow utilities to engineer heat transfer enhancing deposit layers on steam generator tubes and to facilitate removal of the deposit from the tube. The EPRI Steam Generator Management Program and the EPRI Chemistry Program plan to explore the application of this technology to nuclear power plants.

Techniques to mitigate denting of the tubes at the top of the tubesheet will be developed based on an assessment of the underlying mechanism. The operational effects of deposit accumulation at tube support plates will be assessed using a new transient analysis method. An online monitoring technique that uses existing plant measurements to estimate the accumulation of deposits on the tube support plates is under development.

The *PWR Steam Generator Deposit Control and Removal Strategies Sourcebook* will evaluate the characteristics of deposit samples removed from steam generator tubes, historical deposit removal activities, and secondary chemistry that can be used to develop recommendations for an overall deposit control and removal strategy.

Prediction
Two empirical models are under development to estimate deposit accumulation. One will predict deposit accumulation on the tubes in the tubesheet region and the second will predict deposit accumulation on the top tube support plate. In addition, another empirical model will relate deposit accumulation on the tubes to stress corrosion cracking. Generic predictions (*Pressurized Water Reactor Generic Tube Degradation Predictions*) will be developed to estimate the future extent of tube degradation in steam generators based on existing degradation. The results of these two models and the generic predictions are used as input to the overall steam generator life strategy.
The new steam generator thermal-hydraulics software code and deposit formation module will be used to predict the location of deposit accumulation in the steam generator. The new steam generator thermal-hydraulics software code also will overcome deficiencies in the current code (ATHOS/SGAP) by removing geometry constraints to enable evaluation of modern and future steam generator designs.

**Thermal Performance**
A plant's thermal margin decreases when it implements a power uprate, makes other operational changes, or when deposits accumulate on steam generator tubes. A new *Thermal Performance Handbook* will provide a method for factoring thermal performance into a steam generator life management strategy. In addition, utilities and vendors will be able to predict thermal performance using the new steam generator thermal hydraulics code.

**Lead-induced Stress Corrosion Cracking Inhibitors**
Advanced alloys such as 800NG and 690TT are significantly more resistant to stress corrosion cracking than 600MA. However, stress corrosion cracking is possible in 800NG and 690TT in an environment that contains lead. Autoclave testing will be used to develop a fundamental understanding of lead-induced stress corrosion cracking mechanism. Subsequently, mitigation options will be developed.

**Impact**

**Operational Drivers:** Unacceptable levels of deposit accumulation can result in stress corrosion cracking, water level oscillations, less than optimal thermal performance, and/or fatigue failure of steam generator tubes. At the plant level, this can lead to an unplanned outage, an unplanned tube plugging campaign, a reduction in power output, reduction in the maximum allowed power level, and/or primary-to-secondary leakage. These activities can significantly increase worker radiation exposure and plant operating costs.

**Asset Management:** Asset management decisions associated with power uprates, license renewal, and life extension should consider the operating life of a steam generator and the possibility of a first and second steam generator replacement. The models used today to assess steam generator management options and mitigation options will influence decisions if a plant chooses to uprate power or extend the license.

**Regulatory Drivers:** Regulators are concerned that deposit accumulation in steam generators may reach levels that adversely affect steam generator performance prior to implementation of deposit removal activities by utilities. For example, the U.S. Nuclear Regulatory Commission raised this issue in NRC Information Notice 2007-37.

**How to Apply Results**
Upon completion of this work, it is expected that utility program managers and steam generator vendors will have robust models and an adequate knowledge base to develop plant-specific steam generator life management strategies that effectively balance the risk of deposit accumulation, stress corrosion cracking, and thermal performance against other costs and benefits and inform long-term reliability decisions. Specific implementation plans include the following:

- Developing the basis for a plant-specific strategy for managing steam generator deposit accumulation using the new report *PWR Steam Generator Deposit Control and Removal Strategies Sourcebook*.
- Predicting thermal performance consequences of deposit formation on the tubes using the new report *Thermal Performance Handbook* and new steam generator thermal-hydraulics software code.
- Assessing the risk of lead-induced stress corrosion cracking and implementing inhibitors using information in a new report, *Lead-induced Stress Corrosion Cracking: Mechanism and Inhibitors*. 
Boiling Water Reactor Vessel and Internals Project (QA)

Program Overview

Program Description
As boiling water reactors have aged, various forms of operation-limiting stress corrosion cracking have appeared, first in the recirculation piping, then in the reactor pressure vessel internals. Typically, poor materials performance has been addressed by focusing on the specific component or system. This near-term, reactive approach has resulted in costly unplanned outages and expensive weld-by-weld mitigation and repair methods. A longer-term, strategic approach can address a broader range of factors impacting pressure vessel internals.

The Boiling Water Reactor Vessel and Internals Project (BWRVIP) provides an integrated approach for managing materials-related degradation issues in reactor coolant system components in boiling water reactors. The program assesses all facets of operation, maintenance, and repair to develop reliable and cost-effective detection, inspection, and mitigation techniques.

Research Value
BWRVIP maintains alignment with current industry internals integrity concerns affecting boiling water reactors. Research results lead to cost-effective solutions to reduce damage related to stress corrosion cracking; cost savings due to reduced inspection scope, extended intervals between inspections, and improved operating characteristics; reduced personnel radiation exposure; and improved models to better characterize the mitigation of internals components. BWRVIP participants gain access to the following:

- Strategic roadmaps outlining research gaps confronting key issues—such as jet pump vibration and internals degradation—and the collaborative actions needed to address these gaps.
- Technologies and technical guidance that drive increased capacity factors.
- Cost-effective techniques to mitigate stress corrosion cracking of reactor internal components. Economic evaluations indicate that cost savings for implementing hydrogen water chemistry or noble metal chemical application exceed $40 million per plant.
- Cost-effective options for replacing or repairing reactor components.
- Technical solutions to internals inspection needs.
- Industry operating experience and technical insights to optimize inspection requirements, reduce outage critical path times, and inform regulatory decisions.

Approach
The BWRVIP Program takes an integrated approach to degradation management, encompassing assessment, mitigation, and inspection. Through improved inspection techniques, new results from materials research and development, and plant operating experiences, best practices can be deployed to make cost-effective decisions. BWRVIP closely collaborates with other Electric Power Research Institute (EPRI) programs, including Nondestructive Evaluation and Chemistry, to ensure appropriate technologies and technical guidance are effectively integrated into research activities.

There are both base and supplemental components to the BWRVIP research program. The base program focuses on improving the understanding of materials performance in areas such as fracture toughness of stainless steel exposed to high fluence levels, weldability of irradiated materials, and crack growth rates. Because these factors can all impact materials aging, enhanced understanding of their interactions and their impact on materials performance is essential. Research results are provided in the form of guidelines to ensure prompt detection of material degradation, technical reports to support materials performance assessments, and cost-effective tools to more effectively identify and manage degradation for current and extended operations.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate, and execute needed research among multiple entities. For the BWRVIP Program, specific roadmaps
have been developed to address flow-induced jet pump vibration and the degradation of boiling water reactor (BWR) internals. A few roadmaps being led by other programs also will impact BWRVIP, including roadmaps on the welding of irradiated materials and irradiated materials testing. Additional roadmaps will be developed as conditions warrant.

The supplemental portion of the BWRVIP program encompasses research related to assessment, inspection, repair and mitigation.

- **Assessment**: BWRVIP develops inspection and evaluation guidelines that provide the scope for what needs to be inspected and a methodology for evaluating or repairing any indications.
- **Inspection**: BWRVIP develops advanced nondestructive evaluation techniques to improve detection of indications in internals components.
- **Repair**: BWRVIP develops technically based repair criteria for degraded components and equips nuclear plants with information needed to safely plan and implement repairs.
- **Mitigation**: BWRVIP provides guidance for implementing effective chemistry-based countermeasures for stress corrosion cracking of reactor internal components.

Also included in the supplemental portion is an integrated task that provides overall BWRVIP technical and administrative program management (including coordination and engagement with regulators, global entities, and other stakeholders), and a surveillance program for monitoring changes in reactor pressure vessel materials properties due to neutron irradiation.

Nuclear plant owners also can participate separately in a project aimed at maintaining and improving the BWR Vessel and Internals Application (BWRVIA) software code, which performs radiolysis analysis and electrochemical corrosion potential calculations for boiling water reactors. Continued maintenance ensures the BWRVIA code reflects the latest industry operating experience and is equipped to address analytical needs.

**Accomplishments**

The BWRVIP Program supports nuclear power industry efforts to assess and implement effective countermeasures for stress corrosion cracking of reactor internal components. BWRVIP research provides utilities with the information necessary to make cost-effective decisions for managing degradation of boiling water reactor vessel and internal components.

- Issued Nuclear Regulatory Commission (NRC-)approved guidelines on steam dryer inspection and flaw evaluations that define visual inspection requirements for BWR steam dryer assemblies. Baseline inspection results can be compared to subsequent results to assess potential effects of time and power uprates. Developed repair design criteria for steam dryers.
- Published revision 13 of the examination guidelines for reactor pressure vessels and internals in 2010.
- Developed technical basis for inspection relief for reactors using hydrogen injection. This technical basis can be used to inform regulatory decisions regarding the frequency and extent of inspections.
- Issued guidelines for performing weld repairs on irradiated BWR internals, providing a mechanism for determining the weldability of reactor components.
- Compiled data to advance understanding of the relationship between fracture toughness and neutron fluence in highly irradiated stainless steel materials. Also conducted tests to collect crack growth rate data on irradiated stainless steels that can be used to extend EPRI's flaw evaluation methodology to higher neutron doses.
- Designed, developed, and demonstrated a radiographic testing system to facilitate corrosion detection in difficult-to-access BWR drain lines.
- Demonstrated online noble metal chemical addition as a mitigation technique for stress corrosion cracking. Field tests indicate that the technique is effective in reducing electrochemical corrosion potentials and has had no adverse plant impacts. Because the application is performed during operation, 60 critical path hours can be saved versus the classic noble metal application.
Current Year Activities

BWRVIP research and development for 2012 will continue to focus on the technical gaps defined in the BWR Issue Management Tables. Highest priority gaps include the impacts of fluence on the material properties of BWR materials, high-cycle fatigue in jet pump assemblies, and flow-assisted corrosion of the BWR bottom head drain line. Specific efforts will include the following:

- Continue jet pump mitigation hardware testing in full scale jet pump facility
- Support technical review of the steam dryer loads methodology as it works its way through Nuclear Regulatory Commission review
- Continue crack growth and fracture toughness evaluations of highly irradiated materials
- Develop advanced mitigation techniques for stress corrosion cracking
- Optimize inspection and flaw evaluation guidelines for selected BWR internals components

Selected reports will be developed in whole or in part under Title 10 of the Code of Federal Regulations Part 50 (10 CFR50) Appendix B, Quality Assurance, 10 CFR 21, and the EPRI Quality Assurance Program. Additional products may be developed under 10 CFR 50 Appendix B, and 10 CFR 21 at the discretion of the BWRVIP member utilities or EPRI, when such action is deemed appropriate.

Estimated 2012 Program Funding

$9.2 million

Program Manager

Randal Stark, 650-855-2122, rstark@epri.com

Summary of Projects

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<td>Management of Jet Pump Flow-Induced Vibration (Roadmap) (QA)</td>
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<td>Ensuring Reactor Pressure Vessel Integrity Through Eighty Years of Operation (Roadmap) (QA)</td>
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<tr>
<td>P41.01.03.03b</td>
<td>BWR Vessel and Internals Application User Group (supplemental)</td>
<td>The BWR Vessel &amp; Internals Application (BWRVIA) computer code, which performs radiolysis analysis and electrochemical corrosion potential calculations for BWRs, has progressed through several upgrades to enhance its value to the nuclear power industry. Continued maintenance through this project ensures the code reflects the latest industry operating experience and is equipped to address analytical needs. The BWRVIA User Group provides training and ongoing support to all BWR utilities using the model and participating in this program.</td>
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Management of Jet Pump Flow-Induced Vibration (Roadmap) (QA)

Key Research Question

Worldwide, a number of boiling water reactor plants (primarily BWR/4 and /5 designs) are experiencing jet pump degradation associated with flow-induced vibration. The primary causes for jet pump degradation from flow-induced vibration are thought to be turbulent flow through the jet pumps, slip joint leakage flow instability, and pressure pulsations from pump vane passing. Jet pump degradation is generally characterized by wedge and rod wear, but one plant recently experienced substantial cracking in a jet pump riser extending 240 degrees around the circumference. The rate and severity of observed jet pump degradation is increasing. Further, the power uprates being pursued by many plants can lead to increased flow-induced vibration loads on the jet pump assembly.

Approach

The jet pump degradation management research program includes compilation of plant data on jet pump degradation; plant operation and repair histories to understand relationships between plant operation, configuration and degradation; sub-scale phenomenological testing to study the slip joint leakage flow instability phenomenon; and full-scale testing of prototypical jet pump assemblies to assess the effectiveness of vendor-proposed flow-induced vibration mitigation solutions. In addition, lessons learned from testing, and insights from the jet pump degradation and operational history review, will be factored into revisions to jet pump inspection and repair guidelines.

Accomplishments to date include compilation of jet pump degradation and operational history information, sub-scale testing at 1/5th and 1/2 scale to better understand the slip joint instability phenomena, testing using a full scale mock-up of a typical slip joint configuration to assess the relationship between slip joint flow and differential pressure, and fabrication of a full-scale test facility that includes a BWR/4 jet pump assembly and a system to provide slip joint leakage flow up to 180 F. Tests completed to date have reproduced the SJLF instability phenomenon and highlighted the need for on-line measurement of the slip joint gap and well as remote control of the alignment between the mixer and diffuser to provide repeatable test results.

In addition, two vendor proprietary conceptual designs for improved lateral support of the jet pump mixer/diffuser have been developed and are documented in BWRVIP-207 and 210. These designs hold promise to significantly reduce the potential for flow-induced vibration (FIV) damage to jet pump components.

Going forward, the full-scale test facility will undergo modifications to allow full flow testing of both BWR/4 and BWR/5 full-scale jet pump assemblies up to 600 psia and 320 F. Under these conditions, the facility will be capable of reproducing prototypical turbulent pressure loading, slip joint instability excitation, and pressure pulsations from recirculation pump vane passing. The facility will be used to define operating conditions and jet pump configurations that result in "worst case" flow-induced vibration loading. Based on the results, a worst case “demonstration test protocol" will be developed for use in evaluating vendor-developed flow-induced vibration mitigation solutions. At the completion of the EPRI research, the test facility will be made available to participating vendors at their cost to assess the effectiveness of their solutions in mitigating flow-induced vibration loading.

Impact

There are a number of factors that drive the need for timely resolution of the jet pump flow-induced vibration issue, including the following:

Asset Management—Asset management is the primary driver associated with the management of jet pump flow-induced vibration. Jet pump degradation has become one of the most costly BWR material issues, with industry costs currently exceeding $20 million. Several plants have experienced wedge and rod wear even after installing clamps, auxiliary wedges, or labyrinth seals. In 2008, a BWR/5 plant experienced a significant fatigue crack in a jet pump riser that resulted in several months of downtime and required a temporary repair. Currently, the plant is only allowed to operate for a single cycle at reduced power.
Anticipated Growth in the Extent and Severity of Degradation—As more plants pursue power uprates, the potential for more widespread and severe jet pump degradation increases. Power uprates result in higher back-pressure on the jet pumps, which can exacerbate jet pump degradation if mitigation techniques are not available and implemented.

Safety Impact—The integrity of the jet pump assembly is of paramount importance to safe plant operations. The jet pump ensures reflooding to at least 2/3 core height in the event of a concurrent recirculation pipe break, and for some BWRs the jet pump assembly provides a flow path for low-pressure injection.

Potential for Regulatory Action—Although the Nuclear Regulatory Commission (NRC) has not taken action to-date in response to observed jet pump degradation, increased regulatory scrutiny is possible if such degradation is not addressed by industry, particularly if another significant jet pump fatigue crack is identified.

How to Apply Results

Improved jet pump inspection guidance (BWRVIP-41R3 and NRC approved BWRVIP-41R3-A) and repair guidance (BWRVIP-51R1 and NRC-approved BWRVIP-51R1-A) will be developed applying lessons learned during the test program as well as insights from the jet pump degradation and operational history review. Nuclear plant owners will implement the revised jet pump inspection and repair guidance in accordance with NEI-08 implementation guidelines.

Results of BWRVIP testing to investigate jet pump phenomena will allow utilities to assess their relative susceptibility to jet pump degradation based on jet pump design and plant operating conditions. The results also will provide the basis for defining a “demonstration test protocol” to assess the effectiveness of proposed flow-induced vibration mitigation solutions.

Demonstration test results will be provided to BWRVIP utilities by each participating vendor and can be used to inform decisions on potential implementation of one or more jet pump mitigation solutions.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Ensuring Reactor Pressure Vessel Integrity Through Eighty Years of Operation (Roadmap) (QA)

Key Research Question

The ability to monitor and demonstrate the structural integrity of the reactor pressure vessel (RPV) through 80 years of operation is essential to ensure continued operation of the nuclear fleet. For an RPV subjected to years of neutron radiation, adequate demonstration of integrity will become increasingly difficult when applying existing analytical tools and correlations, which were established using the technology and analytical capabilities of the late 1970s.

Revisions to analytical tools, material property databases, and embrittlement correlations are necessary to accurately predict the service life of the RPV. Technical advances are needed for the following:

- Ensure that necessary research data is available to identify and assess fluence- and flux-based damage mechanisms at the levels anticipated through 80 years of operation.
- Establish a damage mechanism-based definition of the region of the reactor vessel that must be evaluated for maintenance of structural integrity. Improving the understanding of these damage mechanisms could help inform regulations.
- Ensure that design materials, end-of-license fluence, and flux are considered to optimize design and fabrication practices for advanced light water reactors.
Ongoing research and regulatory interactions are needed to ensure that the appropriate analytical tools and correlations are developed to analyze and model vessel integrity for safe and efficient operation through 80 years.

**Approach**

The project plan is comprised of the following elements:

**Operational Support through 80 years**
- PWR utilities will implement EPRI's coordinated reactor vessel surveillance program beginning in 2011. This program will generate the high-fluence surveillance data and irradiated material samples needed to support embrittlement correlation databases and damage mechanism assessments at fluences representative through 80 years of operation.
- EPRI and the PWR Owners Group (PWROG) will conduct research and development (R&D) to determine whether the Code and regulatory requirements for RPV integrity could put plants at safety and economic risk in coming decades. This will be accomplished through technical support of American Society of Mechanical Engineers (ASME) Code activities and collaboration with NRC Research in several areas: Master Curve, ASME Section XI Risk-informed (RI) Appendix G, ASME Section XI Appendix E, fluence monitoring, and definition of RPV “extended beltline.”
- EPRI and the PWROG will evaluate the operational impacts related to embrittlement correlations and environmental damage projections for materials and components in the “extended beltline.”
- The BWR Integrated Surveillance Program will be re-assessed to ensure it supports 80 years of operation.

**Data Modeling**
- EPRI will support NRC development of an updated RPV database for generation of new embrittlement trend curves and surveillance data analysis.
- EPRI and the PWROG will assess appropriate stress intensity and flaw distribution models for use in assessing materials/components of the “extended beltline.”
- Data from the International Atomic Energy Association (IAEA) fluence attenuation program will be integrated into the Regulatory Guide 1.99 attenuation model. EPRI will work with NRC and the research community to appropriately identify the conservatism and accuracy of the model to be used.
- EPRI will develop tools and modeling applicable to advanced light water reactor for use in informing design and fabrication specifications.
- EPRI will develop a theoretically derived dislocation-based ferritic steel transition toughness model as input to the Department of Energy (DOE) Light Water Reactor Sustainability Program's material analysis and modeling project.

**Regulatory and Communications**
- Since NRC is responsible for drafting and issuing regulations dealing with irradiation damage mechanisms, EPRI and the PWROG will regularly interface with the NRC Research and Regulation branches.
- EPRI will continue to integrate PWROG, BWRVIP, and MRP activities relative to RPV integrity and regularly communicate their activities with the NRC.

**Impact**

The primary driver for reactor pressure vessel integrity is to ensure that plants can safely and efficiently operate through 80 years without significant operational constraints or mitigation of RPV embrittlement. This encompasses operating restrictions associated with assuring RPV integrity during startup and shutdown activities and the assessment and evaluation of irradiation and other damage mechanisms of the RPV materials in and near the current beltline region.
How to Apply Results
The successful management of reactor vessel integrity issues helps ensure that regulations reflect known technical constraints, but also retain operational flexibility. The end product of this R&D will be EPRI reports that support the bases for ASME Code and NRC regulations affecting RPV asset management.

Additionally, within the next several years, EPRI will develop assessment tools for use in developing site-specific strategies for RPV management. Utilities will use these tools as part of integrated surveillance programs to address 80-year operation.

As data gathering and modeling proceed, the needs of the advanced light water reactor fleet will be considered to ensure that long-term plans envelope advanced designs. Moreover, where program results may affect design or fabrication practices, this guidance will be made available to vendors via the EPRI Utility Requirements Document.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

BWR Vessel and Internals Application User Group (supplemental) (047065)

Key Research Question
Two technologies—moderate hydrogen injection, known as hydrogen water chemistry, and noble metal chemical addition—have been applied in boiling water reactors to mitigate intergranular stress corrosion cracking (IGSCC) by lowering primary water electrochemical corrosion potential. Analytical capabilities are needed to determine appropriate injection concentrations that can maintain electrochemical corrosion potential values at levels that mitigate corrosion. This user group provides information and training on the use of the radiolysis and electrochemical corrosion potential models used in EPRI's BWR Vessel and Internals Application (BWRVIA) software program. Ongoing development of the codes also is evaluated and reported at the annual member's meeting.

Approach
The BWRVIA User Group provides technology that operating BWRs can use to help mitigate IGSCC of reactor piping and internals. The technical project team performs comprehensive reviews of research and development in the areas of radiation chemistry and electrochemical corrosion potential modeling. Sensitivity analyses are performed to evaluate the model's response due to changes in input parameters such as chemical reaction rate constants and dose rate profiles. Adjustments are then made to these sensitive parameters to provide the best possible correlations. Finally, the results of the sensitivity analyses are compared to actual plant data to provide a technical basis for plant application of the calculated results.

Impact
By incorporating the current state of the art in radiation chemistry and electrochemical corrosion potential formulation into the BWRVIA code and benchmarking the revised code against all plant and laboratory data available, this user group ensures the availability of an accurate model for BWR plant owners. The model can then be used, for example, to predict the amount of hydrogen injection needed for IGSCC mitigation of susceptible reactor internals and piping in BWRs.

How to Apply Results
The BWRVIA User Group provides annual training workshops and ongoing support to run the software.
Pressurized Water Reactor Materials Reliability Program (QA)

Program Overview

Program Description
Stress corrosion cracking and other degradation mechanisms in reactor coolant system components have cost the nuclear industry billions of dollars due to forced and extended outages, increased inspection requirements, component repairs and replacements, and increased regulatory scrutiny. Materials aging effects must be effectively managed to ensure safe and reliable functionality is maintained throughout the life of the plant. Further, a better mechanistic understanding of crack initiation and propagation processes and environmental corrosion in the reactor coolant system components is needed to develop reliable predictive models and cost-effective mitigation technologies.

The Materials Reliability Program (MRP) conducts research to identify and resolve existing and potential issues impacting materials in pressurized water reactor (PWR) primary systems. Research activities inform operational and maintenance decisions for existing plants, design choices for new reactors, and regulatory actions pertaining to material aging and degradation mechanisms. These activities are coordinated among pressurized water reactor owners and operators to ensure the plants are aggressively addressing materials degradation and aging and meeting the intent of industry materials initiatives.

Research Value
The Materials Reliability Program assesses industry and regulatory concerns regarding materials degradation in pressurized water reactors and pursues cost-effective inspection, evaluation, and mitigation approaches for addressing degradation. Coordinated activities ensure plants can maintain safe operation and avoid unnecessary outages. Program participants gain access to the following:

- Strategic roadmaps outlining research gaps confronting key issues—such as PWR reactor internals aging management and reactor pressure vessel integrity through 80 years of operation—and the collaborative actions needed to address these gaps
- Detailed inspection and evaluation guidelines for susceptible areas of the reactor coolant system in pressurized water reactors
- Technical bases to inform decisions regarding the extended operation of pressurized water reactors
- Mitigation, repair, and replacement methodologies for aging degradation mechanisms
- Technical analyses and technological options for evaluating and managing in-service degradation to respond to regulatory concerns
- Guidance and tools for fatigue-specific materials management in existing plants and design guidance for new plants to address environmentally assisted fatigue

Approach
MRP takes an integrated approach to degradation management in pressurized water reactors, encompassing assessment, mitigation, inspection, and technical analysis. Through improved inspection techniques, new results from materials research and development, and plant operating experiences, best practices can be deployed to make cost-effective decisions. MRP closely collaborates with other Electric Power Research Institute (EPRI) programs, including Steam Generator Management, Nondestructive Evaluation, Chemistry, and Primary Systems Corrosion Research, to ensure appropriate technologies and technical guidance are effectively integrated into research activities.

There are both base and supplemental components to the Materials Reliability Program. The base portion focuses on reactor vessel integrity, fatigue management, and irradiated materials testing.
• Reactor Pressure Vessel Integrity: The reactor pressure vessel is arguably the most critical safety-related component in the primary pressure boundary of a nuclear power plant. To maintain long-term operation within established limits, the structural integrity of the pressure vessel must be demonstrated under a series of normal operational conditions. Accurate methodologies are needed to analyze vessel integrity for neutron attenuation through the vessel wall, evaluate the effect of irradiation on forged nozzles, and develop models for predicting fracture toughness shifts as vessels operate beyond original design lives.

• Fatigue Management: Reactor coolant system components are susceptible to both thermal and environmentally assisted fatigue. The prospect of life extension highlights the need for more accurate characterization of the effects of high-temperature coolant on component fatigue life, including design rules and inspection requirements. In addition, although industry guidance exists to address high-cycle thermal fatigue degradation in coolant system components due to cyclic stratification induced by swirl penetration, the guidance needs to be evaluated to ensure it adequately addresses this concern for all reactor coolant system components.

• Irradiated Materials Testing: Reactor internal components in pressurized water reactors may be affected by age-related degradation effects. These include general material effects as well as irradiation-induced effects. Data collected through irradiated materials testing can support PWR reactor internals management through extended operation. Long-term irradiation effects are characterized by testing materials removed from retired plants or by conducting irradiations and post-irradiation testing of PWR materials at test reactors.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate, and execute needed research among multiple entities. For the Materials Reliability Program, roadmaps have been developed to address PWR reactor internals aging management and reactor pressure vessel integrity through 80 years of operation. Roadmaps also have been developed in complementary research programs that will impact the Materials Reliability Program, including roadmaps on environmentally assisted fatigue, welding of irradiated materials, and boiling water reactor (BWR) and PWR irradiated materials testing and degradation models. Additional roadmaps will be developed as conditions warrants.

The supplemental portion of the Materials Reliability Program targets research needs related to nickel-base alloy aging management, pipe rupture probability, and reactor internals aging management.

• Nickel-Base Alloy Aging Management: This project develops pragmatic technical guidance for inspecting, mitigating, and managing nickel-base alloys in pressurized water reactors to ensure safe operation and a low probability of safety-significant leakage. By reviewing the latest field results and comparing them to original assumptions in the technical basis for the guidelines, the Materials Reliability Program can identify best practices for managing nickel-base alloys issues. Note that the management of the nickel-base alloys encompasses both the management of the original material, Alloy 600 and its weld metals, as well as the replacement materials, Alloy 690 and its weld metals.

• Pipe Rupture Probability Reassessment: Through a collaborative effort between EPRI and the U.S. Nuclear Regulatory Commission, the Materials Reliability Program is re-evaluating the analytical basis upon which the leak-before-break principle was developed for coolant system piping in pressurized water reactors. The program is responsible for several tasks related to the new calculation, including dissimilar metal weld residual stress measurements, mapping the extremely low probability of rupture (xLPR) calculation, and implementing the xLPR calculation plans.

• Reactor Internals Aging Management: To support the implementation and execution of effective aging management programs, the Materials Reliability Program is developing inspection and evaluation guidelines for pressurized water reactors. These guidelines are developed and updated by integrating information and insights from the irradiated materials behavior database, functionality analysis results, inspection methods, flaw evaluation methods, plant design information, and plant operation data and experience.
Accomplishments

The Electric Power Research Institute's (EPRI’s) Materials Reliability Program supports nuclear power industry efforts to assess and implement countermeasures for degradation mechanisms impacting materials in PWR primary systems. Program research provides utilities and regulatory agencies with the information necessary to make technically sound and cost-effective decisions for managing degradation.

- Developed generic safety- and reliability-driven strategies for materials management for nickel-base alloy components, reactor internals, reactor pressure vessels, and piping degradation due to thermal and environmental fatigue.
- Published a reactor pressure vessel integrity primer as a reference for designing and implementing an embrittlement management program and for complying with regulations for maintaining adequate vessel fracture toughness.
- Developed primary water stress corrosion cracking mitigation technical bases for preemptive weld overlay for nickel-base alloy dissimilar metal welds and for other mitigation methods such as surface treatments (which can avoid higher-cost repair or replacement for certain components).
- Quantified the benefits of zinc addition and hydrogen optimization to mitigate primary water stress corrosion cracking initiation and growth. Such quantification can inform regulatory consideration of modifications to inspection intervals.
- Completed revision 5 of the inspection data survey report, which summarizes inspection data collected from U.S. PWRs. Data include total number of components, the number inspected, the inspection methods, and results for inspections required per program guidelines.
- Developed probability of detection curves to support continued use of leak-before-break assessments for components containing dissimilar metal welds. The curves show with high confidence that inspection procedures are reliable and support leak-before-break principles.
- Developed a predictive model for fracture toughness of ferritic steels in the transition temperature region. Recent work added a crack propagation model to more accurately model temperature effects.

Current Year Activities

Materials Reliability Program research and development for 2012 will continue to focus on reactor internals, fatigue management, and nickel-base alloys aging management. The program also will develop data needed to revise materials management guidelines by conducting projects related to irradiated materials testing, boric acid corrosion, and nickel-base replacement alloy and its weld metals. Key efforts will include the following:

- Revise Alloy 600/82/182 aging management guidance as needed based on industry experience
- Revise reactor internals aging management guidance through materials modeling, inspection method development and demonstration, testing of irradiated materials, and industry experience
- Revise thermal fatigue management guidance as needed based on industry experience
- Define and conduct necessary research to map extremely low probability of rupture calculation
- Assess Alloy 690/52/152 resistance to primary water stress corrosion cracking (includes crack growth rates)

Selected reports have been developed in whole or in part under Title 10 of the Code of Federal Regulations Part 50 (10CFR50) Appendix B Quality Assurance and 10CFR21 and the EPRI Quality Assurance Program. Additional products may be developed under 10CFR50 Appendix B and 10CFR21 at the discretion of the Pressurized Water Reactor Materials Reliability Program (PWRMRP) member utilities or EPRI MRP, when such action is deemed appropriate.

Estimated 2012 Program Funding

$14.7 million
Summary of Projects

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PWR Reactor Internals Aging Management (Roadmap) (QA)

Key Research Question

Reactor pressure vessel internal components in pressurized water reactors may be affected by age-related degradation effects. These include general material effects such as wear, fatigue, and stress corrosion cracking, as well as irradiation-induced effects such as irradiation-assisted stress corrosion cracking, embrittlement, creep, and void swelling. As the PWR plants age, the likelihood of these degradation mechanisms occurring in the internals and structural attachments to the vessel wall increases.

The implementation of aging management plans for various plant components—including the reactor internals—can enhance long-term safety and reliability of PWRs, but advances are needed in three areas:

- Development of inspection and evaluation guidelines based on irradiated material data and aging modeling
- Improvement of inspection techniques
- Development of evaluation, repair, and replacement strategies and techniques.

Approach

Both EPRI and the PWR Owners Group (PWROG) have significant involvement in the Reactor Internals Management effort.

EPRI's Materials Reliability Program has the lead in developing and maintaining the inspection and evaluation guidelines. This includes issuance of the guidelines, dialog with the Nuclear Regulatory Commission (NRC) to support the safety evaluation review, and update of the guidelines to incorporate improvements gained through field inspection results and ongoing testing and modeling research. EPRI also has the lead in collecting irradiated material testing data (see the BWR and PWR Irradiated Materials Testing and Degradation roadmap), documenting the results of field inspections, and validating, refining, and updating the materials model. Finally, the Materials Reliability Program has the lead in assessing repair/replacement needs and developing weld and mechanical repair and replacement guidance as needed (see BWR and PWR irradiated material welding roadmap).

Working with the EPRI Nondestructive Evaluation Program, the Materials Reliability Program has the lead for providing nondestructive evaluation (NDE) system qualification requirements and qualifying inspection techniques for reactor internal components. This includes both evaluations of current techniques for use in these...
applications, as well as development of new or enhanced techniques for plates and bolts. EPRI also will update the inspection standard (MRP-228) as necessary.

In support of inspection planning, the PWROG has the lead in developing baseline plant drawing and fabrication records on a generic basis, for developing a generic methodology for evaluation and disposition of internals inspection results, and for evaluating existing operating experience and analysis results to develop a ranking of component susceptibility (risk). The PWROG also has the lead in developing component-specific evaluation guidance (for example, for guide card wear).

Impact

Regulatory Drivers: Regulatory commitments associated with license renewal and life extension typically require plants to implement a reactor internals aging management program that follows industry guidance. The inspection and evaluation guidelines for reactor internal components (MRP-227) provide the basis to fulfill this commitment. This document has been submitted to the U.S. Nuclear Regulatory Commission for review and safety evaluation. Other countries have similar regulatory commitments even though the regulators and regulatory processes are different.

Regulators also may require approval of repair and replacement strategies and techniques for PWRs, such as the NRC required before it would allow welding to be performed on irradiated BWR internals (see BWR and PWR irradiated material welding roadmap).

Limitations of Inspection Technology: Inspection of reactor internal components will use established techniques to the extent practicable. Because of the lack of experience with these inspections, however, it will be important to assess accessibility and tooling issues, regulatory acceptance of visual inspection techniques, and the applicability of additional techniques for specific degradation mechanisms.

Plant Safety and Operability: The internals are not pressure boundary components so the safety challenge is reduced. However, a few internals do perform safety-related functions.

Limitations on Available Repair/Replacement Guidance: The availability of evaluation, repair, replacement, and mitigation methodologies for reactor internal components is limited. There is an immediate need to develop uniform guidance for the design and qualification of repairs and/or replacement for reactor internals, as well as to develop component and condition-specific repair/replacement options (e.g., mechanical repair techniques). Sufficient information must be available to allow an informed decision whether to continue with a component inspection, evaluation, repair, and replacement management strategy versus full reactor internals replacement.

How to Apply Results

Implementation of research results will be accomplished through a number of key products:

1. An aging management strategy for reactor internal components, including inspection and evaluation guidelines and inspection plans
2. Regulatory approval of the aging management strategy
3. Tools to implement the aging management strategy, such as supporting technical basis documents, templates for utility programs, inspection plans and license submittals
4. Assessment of existing nondestructive evaluation (NDE) methodologies that could support the aging management strategy (inspection standard)
5. Evaluation methodologies and acceptance criteria to evaluate the significance of degradation observed in reactor internal components with respect to operability and safety
6. Updated inspection and evaluation guidelines (MRP-227) based on the results of testing, models, and crack growth curves (see the BWR and PWR Irradiated Materials Testing and Degradation roadmap)
7. NDE technologies optimized for specific application to reactor internal components
8. Design and component-specific evaluations of components most susceptible to degradation (e.g., bolt-loading pattern evaluations)
9. Repair and replacement techniques for susceptible components using mechanical repair designs and weld repair techniques (see BWR and PWR Irradiated Material Welding roadmap); and new replacement materials (see the BWR and PWR Irradiated Materials Testing and Degradation roadmap)

10. Results of plant inspections and operating experience to periodically evaluate the reactor internals aging management strategy (components to be inspected and inspection frequency, as well as component repair and replacement guidance)

11. Methodology for evaluating full reactor internals replacement versus inspect/repair management strategy

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Ensuring Reactor Pressure Vessel Integrity Through Eighty Years of Operation (Roadmap) (QA)

Key Research Question

The ability to monitor and demonstrate the structural integrity of the reactor pressure vessel (RPV) through 80 years of operation is essential to ensure continued operation of the nuclear fleet. For an RPV subjected to years of neutron radiation, adequate demonstration of integrity will become increasingly difficult when applying existing analytical tools and correlations, which were established using the technology and analytical capabilities of the late 1970s.

Revisions to analytical tools, material property databases, and embrittlement correlations are necessary to accurately predict the service life of the RPV. Technical advances are needed to accomplish the following:

- Ensure that necessary research data is available to identify and assess fluence- and flux-based damage mechanisms at the levels anticipated through 80 years of operation.
- Establish a damage mechanism-based definition of the region of the reactor vessel that must be evaluated for maintenance of structural integrity. Improving the understanding of these damage mechanisms could help inform regulations.
- Ensure that design materials, end-of-license fluence, and flux are considered to optimize design and fabrication practices for advanced light water reactors.

Ongoing research and regulatory interactions are needed to ensure that the appropriate analytical tools and correlations are developed to analyze and model vessel integrity for safe and efficient operation through 80 years.

Approach

The project plan is comprised of the following elements:

Operational Support through 80 years

- PWR utilities will implement EPRI's coordinated reactor vessel surveillance program beginning in 2011. This program will generate the high-fluence surveillance data and irradiated material samples needed to support embrittlement correlation databases and damage mechanism assessments at fluences representative through 80 years of operation.
- EPRI and the PWR Owners Group (PWROG) will conduct research and development (R&D) to determine whether the Code and regulatory requirements for RPV integrity could put plants at safety and economic risk in coming decades. This will be accomplished through technical support of American Society of Mechanical Engineers (ASME) Code activities and collaboration with NRC Research in several areas: Master Curve, ASME Section XI Risk-informed (RI) Appendix G, ASME Section XI Appendix E, fluence monitoring, and definition of RPV “extended beltline.”
- EPRI and the PWROG will evaluate the operational impacts related to embrittlement correlations and environmental damage projections for materials and components in the “extended beltline.”
The BWR Integrated Surveillance Program will be re-assessed to ensure it supports 80 years of operation.

Data Modeling
- EPRI will support NRC development of an updated RPV database for generation of new embrittlement trend curves and surveillance data analysis.
- EPRI and the PWROG will assess appropriate stress intensity and flaw distribution models for use in assessing materials/components of the “extended beltline.”
- Data from the International Atomic Energy Association (IAEA) fluence attenuation program will be integrated into the Regulatory Guide 1.99 attenuation model. EPRI will work with NRC and the research community to appropriately identify the conservatism and accuracy of the model to be used.
- EPRI will develop tools and modeling applicable to advanced light water reactors for use in informing design and fabrication specifications.
- EPRI will develop a theoretically derived dislocation-based ferritic steel transition toughness model as input to the Department of Energy (DOE) Light Water Reactor Sustainability Program’s material analysis and modeling project.
- Regulatory and Communications.
- Since NRC is responsible for drafting and issuing regulations dealing with irradiation damage mechanisms, EPRI and the PWROG will regularly interface with the NRC Research and Regulation branches.
- EPRI will continue to integrate PWROG, BWRVIP, and MRP activities relative to RPV integrity and regularly communicate their activities with the NRC.

Impact
The primary driver for reactor pressure vessel integrity is to ensure that plants can safely and efficiently operate through 80 years without significant operational constraints or mitigation of RPV embrittlement. This encompasses operating restrictions associated with assuring RPV integrity during start-up and shutdown activities and the assessment and evaluation of irradiation and other damage mechanisms of the RPV materials in and near the current beltline region.

How to Apply Results
The successful management of reactor vessel integrity issues helps ensure that regulations reflect known technical constraints, but also retain operational flexibility. The end product of this R&D will be EPRI reports that support the bases for ASME Code and NRC regulations affecting RPV asset management.

Additionally, within the next several years, EPRI will develop assessment tools for use in developing site-specific strategies for RPV management. Utilities will use these tools as part of integrated surveillance programs to address 80-year operation.

As data gathering and modeling proceed, the needs of the advanced light water reactor fleet will be considered to ensure that long-term plans envelope advanced designs. Moreover, where program results may affect design or fabrication practices, this guidance will be made available to vendors via the EPRI Utility Requirements Document.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.
Welding & Repair Technology Center

Program Overview

Program Description
High-quality, reliable welds, repair methodologies, and mitigation processes are critical to safe nuclear plant operation. The safety significance of component repairs and replacements emphasizes the need for a high degree of confidence in the integrity of joining processes and implementation techniques. While maintaining this commitment to quality and safety, productivity improvements and new technology development can provide cost savings in maintenance and repair activities.

The Welding & Repair Technology Center develops advanced materials, joining, and repair technologies for nuclear plant applications, contributing to reduced operation and maintenance costs and improved plant availability. The program also supports technical interactions with code and regulatory entities to inform the development and modification of new and existing requirements.

Research Value
Research results from the Welding & Repair Technology Center help nuclear power plants find faster, less costly ways of making repairs using novel welding techniques or by applying existing techniques in new situations. Research results also are used to support technical interactions with regulators regarding code requirements. Program participants gain access to the following:

- Materials, welding, and repair experts across the Electric Power Research Institute (EPRI) and the nuclear industry
- Strategic roadmaps outlining research gaps confronting key issues—such as advanced nickel-based filler metals and welding of irradiated materials in boiling and pressurized water reactors—and the collaborative actions needed to address these gaps
- Demonstrated repair techniques and technologies that improve material performance and enable component life extension
- Benchmarking information from welding programs at nuclear utilities
- Repair options for key components, supplemented by application guidelines, procedures, and training
- Support during implementation of plant repair applications involving material interactions, weld process control, and code requirements
- Techniques that can potentially reduce repair costs and increase plant availability, including temperbead welding, socket weld fatigue solutions, and post-weld heat treatment processes
- Forums for continuous sharing of operating experience, weld program issues, and industry emerging issues

Approach
The Welding & Repair Technology Center combines extensive laboratory capabilities with detailed familiarity with industry and regulatory needs to investigate and evaluate welding and repair techniques. EPRI can replicate welding setups in the field—power supplies, weld heads, and other equipment—to create realistic welding environments in the laboratory. Through participation in many American Society of Mechanical Engineers (ASME) and industry technical committees, the program also ensures that the research results inform code requirements.

There are both base and supplemental components of the Welding & Repair Technology Center Program. The base portion focuses on repair and replacement research, code and standards support, and effective transfer of EPRI technology. As nuclear plant staffs have been reduced, personnel have less time to participate in technology transfer activities, stay abreast of changing codes and regulations, and monitor improved repair technologies and processes. This project supports access to EPRI expertise through meetings and various
information products, including unique repair/replacement applications, a database of welding procedures, repair/welding program assessments, and benchmarking activities.

Regular engagement with code organizations and other technical bodies helps inform the implementation of new repair methods, welding procedures, and weld materials within acceptable safety limits. Base research supports EPRI interactions with ASME (American Society of Mechanical Engineers) and other code and regulatory bodies regarding code cases, revisions, and technical interpretations impacting a wide range of component repairs. Examples include boiling water reactor control rod leakage repair, pre-emptive dissimilar metal weld overlays to address Alloy 600 mitigation applications, and use of specialized methods to seal leakage while under power. Finally, recognizing that the development of repair and replacement technology is an evolutionary process requires continuous sharing of experience among nuclear plants, vendors, and research organizations, the Welding & Repair Technology Center compiles best practices, experience information, and benchmarking data.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate, and execute needed research among multiple entities. For the Welding & Repair Technology Center, roadmaps have been developed for the following issues: welding of irradiated materials for reactor internals, weldability assessment of Alloy 52/52M weld metals, and development of a new high-chromium welding alloy with improved weldability and superior resistance to weld cracking. Additional roadmaps will be developed as conditions warrant.

The supplemental portion of the program evaluates welding materials performance in power plant environments to assess the life of nuclear components and investigates advanced welding and repair technologies to potentially reduce time and cost of repairs. The supplemental portion also provides nuclear plant owners access to case histories, lessons learned data, and technical support in the form of materials and joining evaluations, benchmarking of programs, and procedure development.

Through a separately funded project, participants can participate in the Weld Mitigation Interest Group, which evaluates emerging repair options that address dissimilar weld metal mitigation. The project supports expanded repair and mitigation options that reduce the time, cost, and radiation exposure associated with inspection and mitigation activities, including mechanical stress improvement, inlays, onlays, and overlays.

**Accomplishments**

EPRI's Welding & Repair Technology Center supports nuclear power industry efforts to develop and apply welding and repair techniques that enhance safety, inform regulatory issues, reduce maintenance costs, and improve productivity.

- Issued a resource guide, the *Repair Welding Handbook*, that assists nuclear power plants in choosing appropriate repair techniques and navigating the regulatory approval and code compliance processes.
- Evaluated nickel high chromium weld filler materials for resistance to typical welding related defects, such as direct digital control, hot cracking, and general weldability. Alloy-52-type materials and derivatives have been evaluated to support alloy selection and grading to distinguish heat-to-heat variations.
- Conducted technical analysis to evaluate whether temperbead welding could be used on large-bore piping for larger surface areas. Finite element analysis demonstrated that weld overlays can be applied to areas up to 1000 square inches without generating unacceptable stress levels.
- Demonstrated the feasibility of in-vessel underwater laser beam weld repair of critical nickel alloy welds, eliminating the need to drain the reactor vessel. Areas that have been addressed include seal welding capabilities, temperbead welding, hot cracking susceptibility.
- Developed a roadmap to assist power plant personnel in conducting failure analyses for various components or for directing other organizations responsible for such work, with a focus on metallurgical and mechanical aspects.
- Provided technical support for implementing new technologies, including application guides for advanced welding methods, guidelines for installing and examining dissimilar metal weld overlays, and repair/mitigation of socket weld fatigue failures.
• Supported development of realistic code rules, including new code cases to reduce post-weld examination hold times and use of dissimilar metal weld overlays for stress corrosion cracking mitigation.
• Developed guidance for overlay applications based on lessons learned, best practices, and weld studies to support current technology. Also supported development of new and higher production welding processes such as gas-metal arc welding and dual wire feed gas tungsten arc welding.
• Conducted testing to determine the way in which concrete and reinforcing steel are affected by exposure to boric acid in concentrations typical of spent fuel pool chemistry. Improved understanding of the degradation mechanisms and degradation rates will support life extension decisions.
• Evaluated the application of new repair techniques for high-density polyethylene piping, which is gaining traction as an alternative to steel in low-energy applications.

Current Year Activities
Welding & Repair Technology Center research and development for 2012 will focus on developing repair and fabrication technologies to reduce outage time and expand the availability of repair options that may be performed during plant operation. Specific efforts include the following:
• Conduct failure analysis and stress measurements to assist utilities in repair decisions that are cost-effective, reduce downtime, and improve quality
• Establish welding criteria for repair and mitigation of irradiated material
• Development of temperbead guidance document
• Evaluate advanced filler/welding materials (Alloy 52M) for critical plant repair applications
• Develop training for new repair and replacement engineers
• Evaluate welding methods for small-bore piping and alternative joining methods for socket welded joints
• Provide benchmarking support for utility welding Risk & Reliability (R&R) programs
• Identify repair/mitigation options that address buried piping issues, fuel pool leakage, and components susceptible to stress corrosion cracking

Estimated 2012 Program Funding
$3.3 million

Program Manager
Gregory Frederick, 704-595-2571, gfrederi@epri.com
Summary of Projects

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<td>Welding of Irradiated Materials for PWR and BWR Internals (Roadmap) (QA)</td>
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<td>Alloy 52 Nickel-base Filler Metal Weldability Solution (Roadmap) (QA)</td>
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<tr>
<td>P41.01.05.03</td>
<td>New High Chromium Weld Metal Development and Cracking Mechanisms (Roadmap) (QA)</td>
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<tr>
<td>P41.01.05.04c</td>
<td>Weld Mitigation Interest Group (supplemental)</td>
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Welding of Irradiated Materials for PWR and BWR Internals (Roadmap) (QA)

Key Research Question

The continued operation of light water reactors will require that repairs or replacement of reactor internal components be performed as degradation occurs. Welding plays an important role in the repair or replacement of degraded reactor internals. When reactor internals are subjected to irradiation, however, the weldability of the materials is altered by the formation of helium and can result in helium-induced cracking when these irradiated materials are welded. Most of the research performed to-date has been on irradiated stainless steel. A large gap exists in the understanding related to the weldability of irradiated nickel alloys and reactor pressure vessel steel as well as the ability to utilize special welding techniques to repair high-fluence materials.

Approach

This work is divided into short-term and long-term research and development (R&D) activities. The short-term activities address research needs out to 40 years of operation for welded repairs or replacement to reactor internals. Long-term research activities focus on the development of tools to address degradation that may exist in reactors with 40 or more years of operation, such as the development of models and advanced welding processes for highly irradiated material.

Short-term activities:

- Develop thermal fluence map for pressurized water reactor (PWR) reactor designs
- Develop weldability assessment for the PWR reactor designs
- Refine conventional welding model for predicting the weldability of irradiated stainless steel
- Develop laser welding predictive model for welding irradiated stainless steel
- Develop techniques for applying laser welding to reactor internal repairs
- Refine boiling water reactor (BWR) weldability assessment
Long-term activities:

- Develop a predictive model for the weldability of nickel-base materials
- Research advanced welding process for application on highly irradiated material
- Develop a process model for advanced welding technologies
- Test advanced welding processes on irradiated stainless steel and nickel-base alloys

Impact

There are a number of factors that drive the need for a comprehensive plan to weld irradiated material:

Operational Impacts—In both PWR and BWR reactor designs, there are key structural components that support internal components. If the structural integrity of these components—such as the core support lugs and the jet pump riser leaves—is compromised by degradation, the reactor could be rendered inoperable. No mechanical repair technology currently exists for repairing these components and welded repair or replacements are the only viable option.

Limitations of Existing Welding Technology—Current laser welding technology is only capable of successfully welding material with about 10 atom-part-per-million (appm) helium concentration. This level of helium will be generated in many of the reactor internals locations after about 40 years of operation. New welding technology needs to be developed to extend the weldability of irradiated materials out to 80 years of operation. Hybrid welding technologies such as multiple laser beams that alter the residual stress show significant promise for extending the weldability range of irradiated material, but extensive process development and testing is needed to implement these new technologies.

Cost—The replacement of reactor internals is a costly undertaking. This activity not only involves component removal and replacement, but cut-up and disposal as well. The welded repair is a cost-effective alternative to the repair or replacement option. In some cases, welding also is required to perform replacement of reactor internals.

Coordinated Research Approach—Researching the weldability of irradiated material is difficult for any single EPRI issue management group to fund. It requires the use of hot cell facilities for the experiments and examination of irradiated test specimens. The data produced from these experiments are not unique to one reactor design and can be used by all EPRI issue management groups if the experiments are designed appropriately.

Regulatory—The U.S. Nuclear Regulatory Commission has stated that engineering guidance is required before welding can be performed on irradiated reactor internals. Such guidance has been provided for BWR designs in the form of BWRVIP-97, which has received a safety evaluation review by the Nuclear Regulatory Commission (NRC). A similar document needs to be produced for PWR designs.

How to Apply Results

A comprehensive plan has been developed between EPRI and the Department of Energy to address the weldability of irradiated material. The technology developed through this program will be transferred to industry in three forms:

- Topical reports that contain thermal neutron fluence assessments and weldability maps for each reactor design. These documents will be submitted to the NRC for a safety evaluation.
- Topical reports that document the development of new welding technology that can be used for applications on highly irradiated materials.
- Transfer of newly developed welding technology to vendors for commercialization.
Alloy 52 Nickel-base Filler Metal Weldability Solution (Roadmap) (QA)

Key Research Question
Weld Alloys 52 and 52M are used extensively for repair and mitigation of primary water stress corrosion cracking (PWSCC) in Alloy 82/182 dissimilar metal welds joining critical reactor coolant system components. Alloy 52 and 52M also are specified for use in new PWR designs. Unfortunately, the weldability and crack susceptibility of alloys 52 and 52M varies widely with minor variations of element composition within the ASME material specification limits. Further, crack susceptibility and weldability depend on weld dilution by the base material and on welding process parameters. These issues have caused extensive in-process repair and rework of Alloys 52 and 52M welds, extending refueling outages and costing the nuclear power industry tens of millions of dollars in unexpected maintenance and lost power generation. Research and testing are needed to understand and appreciate the limitations of welding with 52 and 52M for dissimilar metal applications and to develop guidelines to minimize potential for repair and rework.

Approach
The project will follow a logical approach for evaluation of high chromium nickel-base weld alloys. Major project tasks are listed below:

- Perform weldability testing to understand and rank the weldability
  - Computational modeling and laboratory weldability testing
  - Dilution studies
  - Mockup weld testing
- Assess influence of base metal composition to weldability problems
  - Develop threshold levels or charts to evaluate influence of base metals on weldability and crack sensitivity
  - Assess and validate by weldability testing and mockups with NDE
- Evaluate welding processes and influence of process parameters
  - Assess existing, modified, and new welding processes
  - Develop process parameters for existing and for promising new welding process technologies
  - Evaluate welding process and parameters by mockup testing and final NDE
- Application plan
  - Engage leading welding vendors (for example, WSI, WEC, and Areva) to advance existing welding processes and evaluate new welding processes with success potential
  - Support ASME Code rules and engage regulatory agencies for acceptance of new welding processes

Impact
Significant drivers include the following:

Outage Schedule and Cost Impact—The use of 52 and 52M for PWSCC mitigation and repair has caused the loss of tens of millions of dollars in electricity production. Industry experience shows that refueling and maintenance outages are often extended due to repeated re-welding and in-process repair of Alloys 52 or 52M. Until the weldability and crack susceptibility of 52 and 52M are fully understood and adequate composition limits and process controls are implemented to minimize problems, the continued use of these weld metals will likely continue to cause outage schedule extensions and the associated lost plant availability and lost revenue.
**Regulatory Impact**—The U.S. Nuclear Regulatory Commission (NRC) and other global nuclear regulatory agencies are concerned with the poor weldability and crack susceptibility of weld Alloys 52 and 52M. The NRC currently requires the use of 52 or 52M weld metal for repair and mitigation of 82/182 welds and for new PWR nuclear component fabrication.

**PWSCC Mitigation**—Most of the smaller diameter piping dissimilar metal welds have been mitigated by structural weld overlay. The majority of remaining dissimilar metal welds are large-bore, which will require significantly more welding. Welding mitigation options for large-bore applications—such as inside diameter inlays, outside diameter overlays, underwater laser welding, and excavation weld and repair—are considered high-risk activities due to known weldability issues with 52 and 52M.

**Lack of Consolidated Welding Guidelines**—Despite years of effort to optimize welding process parameters and develop specialized welding equipment, the problems with Alloys 52 and 52M continue to plague the nuclear industry. Successful welding is often based on narrow welding process parameter tweaks or on the superior weldability of a single heat of 52 or 52M. Moreover, the optimized welding process parameters or specialized welding equipment developed by a vendor are proprietary. As a result, the reasons for the better than average, or less than optimum, weldability of a specific heat of 52 or 52M are not well understood.

**How to Apply Results**

The products developed from this research will help welding engineers understand the weldability issues and crack susceptibility of 52 and 52M when used for PWSCC repair and mitigation or for new component fabrication. Further, the tools developed will provide utilities, vendors, and fabricators with information that will help minimize rework, improve weld quality, and ensure schedule compliance. Key project deliverables are listed here:

- Index of weldability and crack susceptibility of commercially available high-chromium nickel-base weld metals (for example, 52, 52M, 52MSS, 52i, and low-Fe 52MSS). The index will reflect the relative weldability between commercially available weld metal specifications and between heats within these specifications.
- Matrix of base metal and weld metal composition thresholds and limits that can be used to minimize weldability and cracking problems.
- Evaluation of alternative welding processes (for example, gas metal arc welding [GMAW], laser beam welding [LBW], and hybrid welding) that can be successfully used with high-chromium nickel-base weld alloys.
- Bases documents (as required) and data to support ASME code cases and NRC endorsement of new welding processes and/or other commercially available high-chromium nickel-base weld alloys.
- Final report with data, results, and guidelines.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

**New High Chromium Weld Metal Development and Cracking Mechanisms (Roadmap) (QA)**

**Key Research Question**

Alloys 52 and 52M are high-chromium, nickel-based weld metals developed specifically for their superior resistance to stress corrosion cracking in nuclear power applications. These weld metals are used extensively for repair and mitigation of primary water stress corrosion cracking (PWSCC) in dissimilar metal 82/182 welds. Experience shows that Alloys 52 and 52M are susceptible to weld cracking and have less than optimum weldability. Repair and rework of these weld metals has cost the nuclear power industry millions of dollars. Despite years of effort to optimize welding process parameters and develop specialized welding equipment, the problems with Alloys 52 and 52M continue to plague operating plants and influence new plant deployment.
new high-chromium welding alloy is needed that has the desired mechanical properties and corrosion resistance, but also has significantly improved weldability and superior resistance to weld cracking.

**Approach**

This project will perform fundamental research to understand Alloy 52/52M weldability and cracking issues by literature research, operating experience, and laboratory weldability testing. Concurrently, the project will develop, test, and validate a new high-chromium weld alloy as an alternative to Alloy 52/52M. The project will include composition development, weld alloy manufacturing, welding process and parameter development, and evaluation studies to validate use for repair and fabrication of critical nuclear power components. Proposed plans and tasks include the following:

1. Research and perform laboratory weldability testing to understand fundamental cracking mechanisms and weldability problems with high-chromium nickel-base weld metals
2. Develop alloy composition
   - Evaluate welding behavior and mechanical properties of target composition with modeling and analyses
   - Validate modeled behavior for target composition with small laboratory test samples
   - Manufacture experimental weld wire with target composition
   - Evaluate weldability of weld wire and perform mechanical, corrosion, and crack growth rate testing
   - Assess welding and nondestructive evaluation of alloy composition
     - Assess and develop process parameters for gas tungsten arc and gas metal arc welding
     - Fabricate large-scale mockups and assess impact on nondestructive evaluation
     - Assess feasibility and potential of advanced welding processes (for example, laser welding, magnetic stir, and hybrid)
   - Application plan
     - Engage material manufacturer (for example, Special Metals, and Sandvik) to develop weld metal specification
     - Engage leading welding vendors (for example, WSI, WEC, Areva, MHI, ENSA, and Shaw) to evaluate new weld metal
     - Facilitate acceptance of new weld metal through AWS/ASTM/ASME Codes and Standards

**Impact**

Significant drivers include the following:

**Outage Schedule and Cost Impact**—Between 2006 and 2009, the use of Alloy 52/52M associated with PWSCC mitigation and repair resulted in tens of millions of dollars in lost electricity production. Refueling and maintenance outages are often extended, causing lost generation capacity and increased outage cost, due to repeated re-welding and in-process repair with Alloy 52/52M. Until a long-term solution is realized, the continued use of Alloy 52/52M will likely continue to cause outage schedule extensions with the related lost plant availability and associated lost revenues.

**Asset Management for Operating PWRs**—A number of PWR owners have elected to defer Alloy 82/182 PWSCC mitigation, choosing to inspect instead. This decision resulted from insurmountable Alloy 52/52M weld cracking problems encountered at one plant during installation of a weld overlay on reactor coolant system piping in the spring of 2009. Since that time, only one utility has successfully mitigated Alloy 82/182 PWSCC by Alloy 52/52M weld overlay. Therefore, lack of a high-chromium nickel-base alloy welding solution not only impacts outage schedule and cost, but also is causing incremental inspection costs.

**Regulatory Impact**—The U.S. Nuclear Regulatory Commission (NRC) currently requires the use of a high-chromium (30 wt%) nickel-base weld metal for repair and mitigation of Alloy 82/182 welds and for new PWR nuclear component fabrication. Because of concerns with poor weldability and crack susceptibility of Alloy 52/52M, NRC supports a long-term solution, such as development of a new high-chromium alloy with improved weldability and superior crack resistance.
Lack of a Coordinated Approach—Historically, Alloy 52/52M development has been problem-driven and has occurred on an as-needed basis. Welding problems and cracking that occurred during refueling outages and/or during manufacture and repair of critical PWR nuclear components have driven small modifications or ‘tweaks’ to the base Alloy 52/52M composition. These small modifications or changes to composition may or may not have actually corrected the problem since the fundamental cause of the problem was not thoroughly researched, understood, and corrected. This ineffective approach continues today.

How to Apply Results

New alloy development tools and a new high-chromium alloy with superior weldability will be the main products of this project. Computer modeling and analyses in concert with newly developed small laboratory weldability testing techniques will be used to guide the development of the new high-chromium nickel-base welding alloy. In the past, weld alloy development was normally accomplished by starting with the matching base metal composition followed by systematic additions of minor alloying elements to achieve acceptable welding characteristics. For example, Alloy 52/52M is based on Inconel™ 690 with only minor element additions. Rather than starting with the base metal composition, the new and innovative computational modeling and laboratory weldability testing approach will be used to first formulate an alloy composition that 1) has superior welding performance, 2) is compatible with the base materials to be joined, and 3) maintains the mechanical and corrosion properties required for the reactor coolant system environment in a nuclear power plant.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Weld Mitigation Interest Group (supplemental)

Key Research Question

The repair of dissimilar metal welds continues to provide challenges for even the most experienced vendors and utilities. Complex weld configurations, such as nozzles, offer a mix of base and weld materials including stainless steels, cast stainless steels, nickel-alloys, low-alloy steel, and a variety of weld metals used during fabrication and installation. Common repair methods, such as weld overlays, use a 30% Cr filler metal, which offers exceptional corrosion performance for PWSCC, but also provides a number of weldability challenges. New and emerging repair and mitigation technologies can provide safe, cost-effective options for nuclear plant owners. Evaluation of such technologies is necessary to ensure their application is safe, effective, and can meet code requirements. Candidate technologies may include the following:

- Inlay and only repair technologies for inside diameter (ID) mitigation techniques
- Mechanical Stress improvement process (MSIP)
- Overlay
- Excavated weld repair
- Weldability of Alloy 52, a high-chromium filler material

Approach

The Weld Mitigation Interest Group evaluates emerging repair options that could reduce the time, cost, and radiation exposure related to welding operations; provide enhanced inspectability; expand repair options to include inlays, onlays, excavated weld repair, and MSIP; date filler metal weldability; and document industry experience.

The Weld Mitigation Interest Group provides a forum for exchanging industry experience, solutions, and technology. The Interest Group produces a Stress Corrosion Cracking Repair and Mitigation Handbook to support effective management of primary system components susceptible to stress corrosion cracking (SCC). Related products include evaluation of advanced welding technologies.
Impact

Potential benefits include the following:
- Availability of proven, cost-effective repair and mitigation techniques
- Consistent approach for compiling operating experience and addressing regulatory issues
- Decision tree for identification of mitigation and repair processes for dissimilar Metal Weld locations
- *Overlay Welding Handbook*

How to Apply Results

Participants use technology evaluation results to analyze repair options for future plant application. The *Mitigation Handbook* provides specific guidance that can be incorporated into management and inspection plans for primary systems components susceptible to SCC. Workshop participation provides access to industry experts on weld repair and mitigation.

2012 Products

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<th>Product Title &amp; Description</th>
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<td>Mitigation Handbook</td>
<td>01/31/12</td>
<td>Technical Report</td>
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**Fuel Reliability (QA)**

**Program Overview**

**Program Description**

Fuel failures and other fuel-related issues can have significant operational impacts on nuclear power plants. Fuel failures, for example, have cost some nuclear power plants $40 million or more per event to cover replacement power costs and the costs of a fuel reload. While the industry has made substantial progress in reducing the frequency of fuel failures, continued attention to technical gaps impacting fuel reliability is needed.

The Fuel Reliability Program drives improvements in nuclear fuel performance and reliability based on issues encountered at operating plants around the world. Research addresses multiple aspects of fuel performance and reliability, including fuel failure root-cause resolution, fuel/water chemistry interactions, and operational margins through end of life. The new knowledge is then applied to update fuel reliability guidance and to provide technical feedback for new fuel designs. The program also engages nuclear regulatory agencies and provides technical input regarding fuel-related regulations.

**Research Value**

About $45-$50 billion of nuclear fuel is operating in nuclear reactors worldwide. Optimizing the use of this fuel, while ensuring its safe operation, is paramount to reliable, cost-effective nuclear plant operation. Fuel Reliability Program participants gain access to the following:

- Strategic roadmaps outlining research gaps confronting key issues—such as fuel failures caused by grid-to-rod fretting and foreign objects and regulatory issues related to loss of coolant accidents and reactivity-initiated accidents—and the collaborative actions needed to address these gaps.
- Technical guidance to improve fuel reliability and reduce economic risks associated with fuel failures, which have cost the U.S. nuclear industry more than $300 million over the past decade and the global nuclear industry 2-3 times that amount.
- Global operating experience with all types of nuclear fuel assemblies and reactor types to inform decision-making.
- State-of-the-art software tools to analyze fuel rod thermal-mechanical performance and assess crud and corrosion risk under a range of operating conditions, helping nuclear plants manage a variety of margins.
- Data and technical insights pertaining to the use of high-burnup nuclear fuels. Electric Power Research Institute (EPRI) studies show the industry can save about $200 million/year by moving closer to the current burnup limit and another $200 million/year by increasing the licensed limit.
- Technical studies to inform regulators and ensure regulations impacting nuclear fuel are technically based and not unnecessarily conservative.

**Approach**

The Fuel Reliability Program develops knowledge, guidance, and tools to maximize the reliability of nuclear fuel and core components. The program also participates in international research consortiums to improve fundamental understanding of in-reactor behavior of fuel, cladding, control materials, and other core components.

There are both base and supplemental components to the Fuel Reliability Program. The base program focuses on fuel performance and reliability by quantifying fuel operational margins and identifying fuel failure mechanisms through poolside and hot cell examinations. Projects are cost-shared with fuel vendors to ensure information is factored into subsequent fuel designs, thereby driving improvements in fuel reliability. Performance assessments have been initiated for key boiling and pressurized water reactor designs under bounding conditions. A small but important program area focuses on advancing nondestructive poolside techniques to quantify fuel performance margins, locate failed fuel rods, and identify the cause of failure. An
industry-wide fuel reliability database, FRED, which compiles data on failure root causes, fuel reliability statistics, and good operating practices, also is maintained through the base program.

The supplemental portion of the Fuel Reliability Program addresses technical issues with regulatory implications and technical issues confronting corrosion and crud control in both boiling and pressurized water reactors. With respect to fuel regulatory issues, EPRI serves as the focal point for technical aspects of regulatory issues by participating in experimental programs and performing independent analyses to further understanding of various accident criteria. Current areas of focus include the applicability of existing reactivity-initiated accident and loss-of-coolant accident criteria to high- and intermediate-burnup fuel.

With respect to corrosion and crud control, EPRI research helps to the improve the understanding of and the links between fuel operation, water chemistry, crud, and fuel reliability in both pressurized and boiling water reactors. The research combines fuel surveillance programs and mechanistic studies to develop various guidelines and improve predictive capabilities. Plant demonstrations verify that new technologies and changes in chemistry regimes or core operating strategies do not adversely affect fuel performance.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate, and execute needed research among multiple entities. For the Fuel Reliability Program, roadmaps have been developed to address the technical barriers confronting fuel failures caused by two mechanisms: foreign objects and grid-to-rod fretting. Roadmaps will be developed for additional issues as conditions warrant.

Nuclear plant owners also can participate separately in several supplemental projects:
- Channel distortion in boiling water reactors: collaborative effort to develop short-term guidance and advance understanding of channel distortion, which has negatively impacted control blade operability in a number of boiling water reactor plants
- Falcon User Group: forum for contributing experience and lessons learned with the Falcon fuel performance software code
- Nuclear Fuel Industry Research Program: global consortium of utilities, fuel vendors, and research entities, lead by EPRI, focused on generic, long-term issues and opportunities to ensure safe and reliable use of core materials and components

**Accomplishments**

EPRI’s Fuel Reliability Program distills global experience with nuclear fuel into actionable guidance and insights that drive measurable improvements in fuel reliability.

- Continued healthy fuel examinations to support industry efforts toward zero fuel failures; initiated vendor assessments in 2010 of all healthy fuel inspections as part of “check and adjust.”
- Conducted fuel surveillance campaign at Nine Mile Point to determine the effects of Online NobleChem on fuel crud or corrosion performance. Surveillance provided insight into operation at a site with two units operating under 24-month cycles, one with high duty and the other with lower duty but having longer fuel-operating residence time.
- Evaluated zinc addition in high-duty pressurized water reactors and developed a framework for demonstrating the impact of elevated coolant hydrogen.
- Released Version 3.0 of the Boron-Induced Axial Offset Anomaly Risk Assessment Tool and Version 1 of the updated Falcon software code.
- Performed hot cell examination of fuel from Browns Ferry and identified a new failure mechanism where elevated levels of corrosion generated enough hydrogen in the cladding for the cladding to fail under otherwise insignificant levels of stress. Both cladding corrosion and water chemistry conditions have been improved to avoid future failures by this mechanism.
- Initiated research activities to identify operational impacts related to channel distortion and formulate near-term mitigation guidance. Completed a laboratory investigation of shadow corrosion phenomenon.
- Teamed with the Nuclear Maintenance Application Center and the Institute for Nuclear Power Operations to define and coordinate research tasks to mitigate the threat of foreign materials on fuel reliability.
• Issued five fuel reliability guidelines aimed at enabling industry to achieve zero fuel failures and continued research efforts to resolve gaps identified in guidelines.
• Coordinated failure root cause identification in several fuel failure cases with industry-wide implications, including fuel pellet quality issues in Areva and Westinghouse fuel.

Current Year Activities
Fuel Reliability Program research and development for 2012 will focus on a number of remaining fuel reliability gaps, including the continuing threat of foreign materials, the effects of new water chemistry regimes on fuel reliability, and fuel reliability training. Specific efforts will include the following:

• Perform fuel failure investigations for events with industry-wide implications
• Coordinate input for revisions to water chemistry guidelines for pressurized water reactors, including a better understanding of zinc
• Improve pressurized water reactor risk assessment tool to avoid axial offset anomaly
• Refine risk assessment tool for boiling water reactors to better understand interactions between water chemistry, cladding, and fuel duty
• Conduct round robin testing of post-quench ductility tests and demonstrate rapid loading test for screening new cladding alloys against the latest reactivity initiated accident limits

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977.

Estimated 2012 Program Funding
$17.2 million

Program Manager
Kurt Edsinger, 650-855-2271, KEdsinger@epri.com
**Summary of Projects**

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<td>P41.02.01.04b</td>
<td>FALCON User Group (supplemental) The FALCON User Group provides a forum for nuclear utilities to</td>
<td>further develop the fuel performance and analysis capabilities of the</td>
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<td>P41.02.01.05</td>
<td>NFIR -V and VI (supplemental) Through the Nuclear Fuel Industry Research (NFIR) Program, EPRI</td>
<td>coordinates research on behalf of an international consortium of utilities,</td>
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<td>fuel vendors, and research laboratories. Research activities focus on generic,</td>
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<td>long-term issues and opportunities to ensure safe and reliable use of light</td>
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**PWR Grid-to-Rod Fretting Failure Mitigation (Roadmap) (QA)**

**Key Research Question**

Grid-to-rod fretting (GTRF) is the predominant fuel failure mechanism in U.S. pressurized water reactors, accounting for more than 70% of failures since 2000, or about 40 failed assemblies per year. Measurements on AREVA and Westinghouse fuel designs thought to be resistant to GTRF suggest fretting margins are increasing as plants transition to these designs, but they have not accumulated sufficient experience under challenging operating conditions to be considered proven solutions. Other measurements have shown wear in unexpected places, demonstrating that understanding in this area is insufficient. Certain plant designs, including those by Combustion Engineering and Babcock & Wilcox, are known to be more challenging for GTRF resistance. In addition, GTRF-resistant designs may have non-optimized thermal performance, requiring further understanding to optimize fuel performance and reliability.

**Approach**

Near-term and long-term research are planned in several areas:

- Information gathering (operational experience database, gap analyses, plant comparison)
- Surveillance (inspections, hot cell exams)
- NDE technology development
- Modeling (discrete and coupled, involving fluid dynamical, mechanical, and tribological)
- Testing (flow, design, and material/manufacturing processes)
- Guidance (core design and operational mitigation strategies; monitoring / surveillance / inspection best practices; GTRF guideline revision)
Most of the research effort will focus on two areas:

- **Flow-Induced Vibration and Excitation**—Design and/or degradation of internal structures, coolant flow paths, and fuel assemblies result in turbulent cross-flow conditions that cause fretting wear through relative motion and contact of grid supports and fuel rods. Flow-induced vibration is specific to core designs and typically occurs due to the following:
  - Baffle jetting or cross-flow due to baffle plate gaps, holes, or slots
  - Core outlet and inlet cross-flow (Lower Plenum Anomaly)
  - Fuel assembly and/or rod self-excitation
  - Cross flow due to mixed core transition

- **Material & Fuel Design**—GTRF susceptibility is enhanced by fuel-rod cladding and grid materials susceptible to excessive creep, growth, and wear. Moreover, fuel assembly design features may increase the relative motion and effects of contact area and pressure between cladding and grid supports, including the following:
  - Grid-to-rod clearance (function of cladding creepdown, grid growth, and spring and dimple relaxation)
  - Span distance
  - Shape and contact area of springs and dimples
  - Spring pre-tensioning (at beginning-of-life to end-of-life)
  - Irradiation-induced creep and growth
  - Cladding thickness and corrosion
  - Wear of cladding and coatings

To expedite this effort for 2011, FRP’s Base Technical Advisory Committee (TAC) will likely need to fund a significant fraction of the near-term scope within the existing budget. Fuel suppliers will need to continue to maintain or accelerate the testing efforts they have underway and will likely need to invest more in cosponsoring examination efforts for current designs and advanced designs. The Base TAC will continue to integrate with the activities of fuel suppliers, Institute of Nuclear Power Operations (INPO), and PWROG to ensure comprehensive and extending to industry-wide solutions with minimal duplication of effort.

**Impact**

There are a number of factors that drive the need for a carefully designed plan to fully understand and mitigate GTRF-induced failures, including the following:

- **Zero Failure Goal**—The industry goal to achieve zero fuel failures by the end of 2010 will not be attained due to GTRF failures and, therefore, requires a more coordinated approach.

- **Operational Impacts**—Plants that have experienced GTRF fuel failures must take into account a number of parameters—including core and fuel designs, plant modifications, and fuel handling—to maintain adequate margin against future GTRF failures. These parameters typically result in more restrictive core operations and performance, negatively impacting capacity factor and fuel utilization while increasing the amount of work for reactor operators and fuel performance engineers.

- **Cost**—Many plants are incurring costs from reduced capacity, additional fuel inspections, clip installation, fuel reconstitution/recage, premature fuel discharge (and storage), risk/margin assessments, and less efficient (high leakage) core designs. Operational deficiencies also can impact plant finances in terms of interest and insurance rates.

- **Verification of New Fuel Designs**—New fuel designs, manufacturing processes, and materials must be sufficiently tested and validated (both out- and in-reactor) for long-term operation. New designs also must capitalize on improved understanding of the effect of plant conditions on GTRF susceptibility and be flexible to accommodate more challenging plant conditions (such as aging issues, power uprates, transition/mixed-design cores, longer cycle lengths, higher fuel duty, and burnups).
- GTRF Detection Technology—Fuel failures typically begin as small breaches in the fuel cladding and may not be 100% detected using current technologies (e.g., sipping, ultrasonic testing, and eddy current). In some instances, fuel assemblies associated with undetected failures have been reinserted for a subsequent cycle. New and more reliable technologies are needed to improve leaker detection.
- Plant Dose—GTRF-induced failures can result in substantial source term affecting plant worker dose. Thus far, operational experience has shown that dose levels are still within Technical Specifications, but vigorous monitoring of coolant radiochemistry is necessary to ensure limits are not exceeded.

How to Apply Results

There are four components of implementation with this roadmap:

Updated Guidance: Improved GTRF guidance will allow utilities to increase margins with any/all of the design and operational choices available to them.

Improved Fuel Designs: Program results will be used by fuel suppliers to design, test, and demonstrate fuel designs with improved GTRF resistance.

Improved Nondestructive Evaluation Techniques: NDE advances to quantify fuel rod wear quickly and efficiently on a significant population of fuel rods will allow utilities to track long-term performance of their operating fuel and make adjustments as necessary to ensure reliable operation.

Advanced Modeling: Utilities will have access to more reliable modeling tools (including fuel supplier codes) to manage GTRF for margin assessments of core design and/or plant modification.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977.

Mitigation of Fuel Failures Caused by Foreign Material (Roadmap)

Key Research Question

Poor foreign material exclusion (FME) practices can lead to fuel cladding failures. Between 2000 and 2010, 19 PWRs in the United States experienced debris-related fuel failures in 28 cycles. In the same period, 19 BWRs (54% of the fleet) experienced this type failure mechanism in 31 cycles. In the case of BWRs, five units had to shut down mid-cycle on seven occasions to offload leaking assemblies. The average duration of each outage was 12 days. Fuel failures challenge plant availability and escalate operating costs. They also increase plant personnel radiation exposure and contamination events and negatively impact outage schedules.

Approach

A defense-in-depth approach is required to eliminate all forms of foreign material from the reactor and connected systems. Three strategies are needed to eliminate debris-related fuel cladding failures.

Eliminating the Introduction of Foreign Material

- Plant personnel must improve their implementation of FME programs and practices. Twenty percent of all Maintenance Areas For Improvement are related to foreign material exclusion (FME). In February 2011, INPO released Revision 1 of 07-008, Guidelines for Achieving Excellence in Foreign Material Exclusion (FME), to help utilities develop and improve the implementation of FME programs and practices. From the date of issue, utilities have approximately 6 months to perform a gap analysis that benchmarks existing programs against the new Guidelines.
- EPRI will revise Nuclear Maintenance Applications Center: Foreign Material Exclusion Guidelines—Product ID 1016315, following the utility gap analysis of INPO 07-008, Rev. 1.
- EPRI will develop two new video-format training tools to include in utility training programs: 1) a wire brush fundamentals and use DVD, and 2) an update to Fuel Reliability Program: Foreign Material Exclusion—Striving for Industry Excellence (DVD—Product ID 1014962.
Material and service providers will incorporate FME techniques and culture into their business practices. EPRI has developed standardized FME procurement requirements for material and service purchases. Utilities will incorporate these standardized FME procurement requirements into the appropriate material and service purchases.

**Removal of Existing Foreign Material**

- EPRI will develop guidance for utilities to address when below-the-reactor-vessel-core-plate inspections for foreign material should be performed. These inspections are high risk but potentially high-reward activities. A decision tree process approach will provide utilities with consistent and standardized guidance for evaluating the implementation of this activity.
- Utilities will implement a program that systematically searches for and removes existing debris from plant systems and components. This program should include borescope, robotic camera, velocity flushes, tank inspections, and periodic inspection of other locations where debris might settle or accumulate.

**Debris Resistant Fuel and Plant Features**

- Fuel vendors continually upgrade their fuel products to improve performance. Bottom nozzle debris filters have evolved over time, and the latest generation products filter very small debris. The new generation debris filters are currently being placed in service and require monitoring for effectiveness.
- Some BWRs have installed feedwater strainers to filter out debris that would otherwise reach the reactor vessel. These installations warrant monitoring for effectiveness and broader application.

**Impact**

Nuclear Safety—Fuel cladding is the first barrier to a fission product release to the general public, and all reasonable actions to maintain the integrity of this barrier should be taken.

Personnel Radiological Factors—Even small breaches of the fuel cladding can cause increased plant radiation fields and increase plant worker contamination events. Keeping worker integrated doses and contamination events as low as reasonably achievable (ALARA) is the cornerstone of a good radiological health program.

Operational Drivers—Fuel failures drive up operating costs and can lead to unplanned outages, particularly in BWRs. These effects can impact public confidence and increase regulatory scrutiny.

Industry Commitment—For the reasons stated above, utility chief nuclear officers pledged to support a fuel integrity initiative to reduce fuel cladding failures (initially the “Zero by 2010” initiative). This effort is open-ended.

**How to Apply Results**

Completion of this work is expected to result in the following:

- Alternate products that have been developed will be used where appropriate in lieu of wire brushes for most applications. Strands of small wire from wire wheels and brushes used during maintenance activities are one of the most common foreign materials causing fuel cladding failure.
- Utilities will incorporate FME techniques and culture into their business practices. Utilities will ensure material and service providers institute standards that preclude the introduction of foreign material into components and systems.
- Utilities will implement a program that systematically searches for and removes existing debris from plant systems and components. Areas of high risk and potential for debris accumulation need to be identified and resources committed to search and removal.
- Fuel suppliers will continue development of and improve debris filters for their fuel products. Controlled testing will be conducted prior to introducing these products into commercial reactors. Once introduced commercially, a period of performance monitoring will be required to assess improvement gains.
**BWR Channel Distortion (supplemental) (052392)**

**Key Research Question**

Seventeen of the 35 BWRs in the United States have reported control blade interference due to channel distortion in the last 8 years. Affected fuel designs include Zircaloy-2 channels manufactured by all three U.S. fuel vendors. Multiple mechanisms have been identified that can give rise to channel distortion, which manifest as bow, bulge, and twist. Recent experience indicates that fuel vendor models cannot sufficiently predict the channel distortion.

**Approach**

A Channel Distortion Industry Action Plan (CDIAP) has been developed to coordinate efforts among utilities, EPRI, the BWR Owners Group, fuel vendors, and INPO. The purpose of this plan is to provide the industry with an effective short-term and long-term strategy to address channel distortion as an operational issue. Integral to this plan is to understand each mechanism of channel distortion at the scientific (or mechanistic) level. Therefore, the goals of the plan include the following:

- Update guidance to effectively manage channel distortion until more effective solutions are available
- Collect and analyze channel performance data, including operational performance data, poolside dimensional measurements, and hot cell examination data
- Develop a mechanistic understanding of channel distortion and identify gaps in understanding
- Conduct more detailed examinations to understand and quantify each distortion mechanism
- Develop improved distortion models and provide to fuel vendors for incorporation into their channel management tools; validate the performance of distortion models via examination and surveillance
- Ensure proposed materials solutions are appropriately validated

**Impact**

Despite substantial past efforts to understand the issue, recent experience indicates channel distortion is not predicted well enough. Results from research in this area will lead to model improvements that ensure core designs are less susceptible to channel distortion.

**How to Apply Results**

The initial effort to provide channel distortion guidance will be directly applicable by the utility. The information from poolside measurements and laboratory analysis will be used to improve the models that utilities use to guide core design and manage operational aspects of channel distortion.

**FALCON User Group (supplemental) (006165)**

**Key Research Question**

This project provides a forum for FALCON users and developers to share lessons learned and discuss code improvements necessary to enhance nuclear fuel reliability and performance. FALCON is the Electric Power Research Institute's (EPRI's) thermal-mechanical fuel performance code for steady-state and transient applications.

**Approach**

The user group meets roughly once per year. The user group provides guidance in upgrading the FALCON code in response to industry needs and operating experience. Support also is available from EPRI throughout the year.

**Impact**

The user group allows members to share experience, suggest improvements, and maximize the value they receive from the code.
How to Apply Results

Through user group meetings and other communication mechanisms, participants share operating experience with the FALCON code and identify software improvements to address emerging needs.

NFIR -V and VI (supplemental) (058707)

Key Research Question

The nuclear fuel industry has long recognized the need for a generic, long-term R&D program to ensure safe and reliable use of light water reactor core materials and components. Since 1982, EPRI has led the Nuclear Fuel Industry Research (NFIR) group, an international consortium of utilities, fuel vendors, and research laboratories. The NFIR program seeks to understand fundamental in-reactor behavior of fuel, cladding, control materials, and other core components and to share this valuable knowledge with the industry.

Approach

In the current phase (NFIR-VI, 2010-2015), planned projects to be conducted through NFIR will address topics such as the following:

- Channel bow (irradiation test)
- Hydrogen pickup in high-burnup BWR fuel
- Pellet cladding interactions (test reactor irradiation)
- Thermal stability of irradiation and cold work defects
- Fuel pellet properties at high burnup (e.g., melting point, helium release, and additives behavior)

Impact

- NFIR enables cost-effective, collaborative work on generic issues important to the industry, but not necessarily tied to a specific fuel design or plant operation.
- All major vendors, international utilities, and research labs are members of the program wherein utility members can advise on fuel R&D issues affecting all vendors, not just their own fuel supplier.
- Through NFIR participation, members have the opportunity to network with industry experts from around the world and learn about current and anticipated issues.

How to Apply Results

NFIR-VI projects will continue to provide fundamental materials properties and behavior data that lead to improved fuel products by improving the knowledge about the behavior of fuel and core components materials. The knowledge and data obtained through these projects will be factored into fuel design modifications, new fuel designs, and operational strategies targeting higher fuel reliability.
Used Fuel and High-Level Waste Management (QA)

Program Overview

Program Description
Nuclear power’s long-term viability depends on safe, cost-effective management of used fuel and high-level waste. An integrated solution encompassing fuel cycle closure, centralized interim storage, transportation, and permanent geologic disposal is achievable, but requires significant research and technology development.

The Used Fuel and High-Level Waste Management program examines a range of complex scientific and technical issues affecting waste management, including advanced fuel cycles, used fuel transportation, geologic disposal, and on-site and interim storage requirements. Research related to these issues informs regulatory decisions on waste management and provides insight into technical advances required to develop an integrated solution.

Research Value
Better understanding of the options available for managing the technical, economic, environmental, and institutional aspects of high-level waste and advanced fuel cycles is needed to inform decision-making. Electric Power Research Institute’s (EPRI’s) Used Fuel and High-Level Waste Management program conducts research to characterize the various technical risks and risk mitigation options related to used fuel storage, transportation, and disposal. The program also pursues the identification of promising technologies for closing the fuel cycle, which could lead to significant increases in the amount of energy extracted from uranium and to reductions in the volume of waste requiring long-term geologic disposal. The Used Fuel and High-Level Waste Management program members gain access to the following:

- Strategic roadmaps outlining research gaps confronting key issues—such as advanced nuclear fuel cycles and extended used fuel storage—and the collaborative actions needed to address these gaps
- Technical guidance to support operation of long-term on-site and geologic repositories
- Technical basis to resolve generic used fuel storage and transportation issues impacting plant operability, license renewal, decommissioning, and the licensees’ ability to move fuel off-site
- More efficient dry storage and transportation canister designs that offer economic savings and enhance the licensees’ ability to move high-burnup (>45 GWD/MTU) used fuel off-site

Approach
The Used Fuel and High-Level Waste Management program develops knowledge, guidance, and tools to reduce the risks and maximize the technical options for safe, cost-effective handling, storage, and disposal. The program incorporates global experience with fuel handling and fuel reprocessing, and collaborates with global entities on cross-cutting research addressing the nuclear fuel cycle and supporting elements.

Base research activities address four technical areas:

- Used Fuel Storage and Transportation: This project develops technical bases to assist in resolving generic issues associated with used fuel storage and transportation. Such issues include licensing, used fuel pool criticality, risk-informed treatment, and high-burnup fuel. Activities conducted in this project support efforts to inform potential regulatory actions. For example, EPRI is developing benchmarking information to address uncertainties in calculating criticality in used pools. Research also will evaluate the impacts of the March 2011 events at the Fukushima Daiichi nuclear plant on general understanding of used fuel pool failure mechanisms and risks.
- Neutron Absorber Materials Studies: This project organizes annual meetings of neutron absorber material users and manufacturers to share experience and guide future research. It also maintains an up-to-date handbook on available neutron absorber material information related to material properties, manufacturing processes and field experience. Project activities can result in more efficient management...
of existing neutron absorber materials, help maintain choices between available materials, and guide future development of new materials.

- Advanced Fuel Cycle Modeling and Waste Management: This project develops nuclear fuel cycle models that can track materials and radionuclides through the system and determine the appropriate mixture of light water reactor and fast reactor technology for both startup and steady-state operation. Detailed sensitivity and uncertainty analyses are conducted to shed light on research and development (R&D), health, and economic risks. This project also evaluates the readiness of the exiting and near-future light water reactor fleet to utilize mixed-oxide fuel.

- Very Long-Term Used Fuel Storage: Given the lack of options for ultimate disposition of used nuclear fuel in many countries, continued storage in the original dry storage systems may be warranted. This project identifies technical and regulatory issues that need to be addressed to achieve very long-term dry storage in existing canisters. Research will pursue development of a management plan that includes surveillance, testing, and eventual repackaging.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate, and execute needed research among multiple entities. For the Used Fuel and High-Level Waste Program, roadmaps have been developed to address advanced nuclear fuel cycles and very long-term used fuel storage. These roadmaps outline the technical barriers confronting these issues, the collaborative research needed to resolve them, and the manner in which the research results should be implemented. Additional roadmaps will be developed as new strategic objectives emerge.

Through a separate supplemental project, nuclear plant owners can contribute to the continued development, maintenance, and sharing of lessons learned for the Cask Loader software program. Cask Loader provides guidance to optimize the choice of used fuel to be moved from wet to dry storage and to reduce documentation errors.

**Accomplishments**

EPRI's Used Fuel and HLW Management program provides specialized technical analysis to ensure the safe, economic handling, and disposal of used fuel and HLW and to inform decisions regarding the viability of various nuclear fuel cycles.

- Assessed the economic and radiation impacts associated with the early movement of used fuel to dry storage. The study determined that an industry-wide requirement to move used nuclear fuel into dry storage after 5 years of cooling would result in a net present value cost increase of $3.6 billion compared to current practice.

- Launched a new project to develop the technical bases for extended (>60 years) used fuel/high-level waste storage. To encourage industry technical consensus, EPRI hosts regular workshops to coordinate parallel national and international efforts in this area.

- Issued the *Handbook of Neutron Absorber Materials for SNF Transportation and Storage*, which assists utilities in selecting and managing such materials in the used fuel pool and in dry storage and transportation systems.

- Collected data on high-burnup advanced cladding properties to support their continued use while allowing for used fuel storage and transportation.

- Completed a multi-volume review of technical issues related to geologic disposal of used fuel and high-level waste. The review addresses topics such as site selection, regulations, lessons learned, and global repository experience.

- Evaluated the key attributes of sustainable nuclear fuel cycles and the most promising pathways and technological challenges in a report titled, "Advanced Nuclear Fuel Cycles – Main Challenges and Strategic Choices." The analysis illustrated how country-specific differences in energy contexts—such as availability of domestic fossil resources, reliance on nuclear generation, government-industry relations, and political decision-making—may lead to different nuclear fuel cycle implementation strategies.
• Conducted several nuclear fuel cycle cost comparisons: front-end nuclear fuel cycle costs using reprocessed uranium, fuel cycle cost comparison between once-through and plutonium multi-recycling in fast reactors, and fuel cycle cost comparison between once-through and fully closed cycles.
• Completed a report outlining the technical considerations that utilities should be aware of when evaluating their readiness to use mixed oxide fuel (MOX) in existing and new reactors.
• Developed cost estimates evaluating trade-offs between front-end issues (for example, additional uranium ore versus cost of conversion and enrichment), back-end issues (for example, direct disposal of all used fuel versus cost of reprocessing with direct disposal), and centralized storage issues (for example, storage facility size and operating lifetime).
• Released Cask Loader Version 2.2a, which assists utilities in planning and executing the loading of spent fuel assemblies and their components into dry cask storage. The new version optimizes cask loading based on cost and schedule constraints and maintains data for US DOE and NRC reporting.

Current Year Activities

Used Fuel and HLW Management program research and development for 2011 will focus on generic used fuel storage and transportation issues and on evaluating strategies for the future of a sustainable nuclear energy fuel cycle. Specific efforts will include the following:

• Conduct work, as appropriate, to develop “lessons learned” for used fuel pool risks from the March 2011 events at the Fukushima Daiichi plant in Japan
• Establish benchmarks for establishing depletion uncertainties necessary for criticality calculations in used fuel pools
• Develop technical bases to inform licensing decisions regarding high-burnup used fuel transportation systems
• Obtain additional data on advanced nuclear fuel claddings to support used fuel storage, transportation, and disposal
• Develop a dynamic model for the introduction of advanced fuel cycles
• Develop technical bases on which to base decisions regarding very long-term (>60 years) used fuel storage

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977.

Estimated 2012 Program Funding

$3.0 million

Program Manager

John Kessler, 704-595-2737, jkessler@epri.com
Summary of Projects

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<td>Fuel Works/Cask Loader User's Group (supplemental)</td>
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Advanced Fuel Cycles (Roadmap)

**Key Research Question**

To retain nuclear energy as an important electricity generation option in a low-carbon world, nuclear power must overcome critical challenges in capital cost, natural uranium resource utilization, waste disposal, and proliferation while maintaining its current safety and reliability record. Overcoming these challenges—especially dramatically increased use of energy from the atom—will the nuclear industry about the evolution of the nuclear fuel cycle: what types of reactors and nuclear fuels to deploy, the time frame over which these technologies should be deployed, how to manage commercial spent nuclear fuel, and what methods to use for disposing spent fuel and nuclear waste. In short, the industry will have to determine whether used nuclear fuel is to be treated as a “waste” or as a “resource”, and then act accordingly.

**Approach**

Key EPRI capabilities emerging from advanced fuel cycle RD&D will provide the following for the nuclear industry:

1. A reasoned, transparent, traceable basis for evaluating fuel cycle options that have the potential for future deployment. Identification of the required steps for transitioning from light- or heavy-water reactor technologies to advanced fuel cycles through the deployment of new technologies will be documented.
2. The capacity to independently evaluate the benefits and drawbacks of fuel cycle options over time in terms of economics and material and energy flows.
3. Independent assessment of human and environmental health impacts arising from fuel cycle options.
4. A straightforward metric for evaluating the nonproliferation and security risks associated with fuel cycle options.

EPRI will deliver these capabilities through a suite of assessment tools based on a platform of software, simplified relationships, and clear decision-making and evaluation guidelines. EPRI will pursue phased development of an advanced fuel cycle assessment toolbox with an emphasis on flexibility and adaptability to anticipate the evolution of technology, policy, and the needs of EPRI members. The core theme of project execution is collaboration with the intent of leveraging the resources and expertise of other entities, notably the U.S. Department of Energy, the national laboratories, and key utilities and technology vendors. EPRI will retain responsibility for maintenance and use of this toolbox, which will evolve based on end-use member experience.

**Impact**

**Economics and Sustainability:** Continued and expanded use of nuclear power may be predicated on improved economics and sustainability. These developments may require evolution of the present nuclear fuel cycle to provide a flexible framework that can adapt to changes in technology and national policy. The technical and economic conditions for breakthrough of these advanced technologies are challenging, as they encompass
not only reactors, but also dedicated reprocessing, fuel fabrication, and waste disposal facilities. Their competitiveness may be anticipated on paper, but it will eventually have to be proven by experience prior to widespread implementation by the nuclear industry.

**Policy Uncertainty:** In the United States, fuel cycle policies are in a state of confusion following the Department of Energy’s withdrawal of the license application for a geologic repository at Yucca Mountain and the demise of the Global Nuclear Energy Partnership to recycle fissile material from spent fuel into new fuel assemblies. These developments mean that commercial used nuclear fuel in the United States can only be stored at the reactor sites where it was generated. This dilemma is shared by EPRI’s members outside the United States without national centralized storage or waste disposal facilities. The “Blue Ribbon Commission on America’s Nuclear Future,” established by the United States Secretary of Energy, is conducting a comprehensive review of policies for managing the backend of the nuclear fuel cycle, including all alternatives for the storage, processing, and disposal of civilian and defense used nuclear fuel, high-level waste, and materials derived from nuclear activities. The Commission is expected to make a number of pointed recommendations with regard to institutional and legal arrangements for the management of spent fuel and nuclear waste and to support RD&D on selected topics toward the safe and cost-effective future application of spent fuel reprocessing and recycling. It is likely that many of the Commission’s recommendations will be relevant to EPRI’s non-U.S. members, as well.

**Advanced Technologies:** Many different fuel cycle options are on the table. Some of them represent dramatic changes compared to the light- or heavy-water reactor systems the nuclear industry is currently familiar with. What works on paper, however, does not necessarily work on an industrial scale in the context of efficient power generation. The impact of complex fuel cycles on power operation is generally lacking in existing analyses, which typically focus on natural uranium utilization, waste minimization, and non-proliferation. Therefore, the path toward economic implementation of advanced technologies by the nuclear industry requires careful consideration.

**How to Apply Results**

Success will ultimately be measured in terms of the extent to which ideas from EPRI and its membership inform the RD&D programs pursued by governments and other relevant entities in the United States and abroad. On behalf of EPRI’s membership, EPRI will position itself as a collaborative thought center for advanced fuel cycle modeling and analysis through a workshop series recognized as the principal opportunity for productive discussion, interaction and collaboration among government, academia, and industry. EPRI also will influence the evolution of key model and assessment tools through the establishment of (or leadership in existing) user groups.

EPRI is not nor should be in a position to lead global efforts to develop a closed fuel cycle; the lion’s share of the R&D will be borne by the government or private industry. Hence, the use of EPRI tools will identify technology gaps, risk tradeoffs, and implementation issues to inform decision-makers about benefits and drawbacks of proposed advanced fuel cycle scenarios. EPRI will work closely with organizations such as the U.S. Department of Energy to provide input to the R&D plans for these organizations such that their plans result in realistic and economic options for the nuclear industry.

**Extended Used Fuel Storage (Roadmap)**

**Key Research Question**

Options for handling and managing used fuel and high-level waste are limited. Currently, no ultimate disposal facility exists for either used fuel or high-level waste anywhere in the world, and reprocessing is limited as well. The use of dry storage, therefore, is increasing and will likely continue for many decades, perhaps centuries. During these extended periods of used fuel and high-level waste storage, all stakeholders need confidence that the safety functions of storage and transportation are maintained.
Approach

EPRI has a two-pronged approach to evaluating the lifetime of existing used fuel dry storage systems. Through the Extended Storage Collaboration Program, formed in November 2009, EPRI is developing the technical bases to ensure safe, extended used fuel storage (greater than 60 years), and future transportability. Many organizations are being engaged in this effort (industry, regulators, government labs) to enlist a wide range of perspectives and technical expertise.

The scope of the Extended Storage Collaboration Program includes the following:

- Evaluating the technical factors involved in ensuring the safe extended storage of commercial light-water reactor used fuel (including storage systems and fuel integrity)
- Providing the technical bases to support transportability (at time of transportation) after extended storage
- Addressing issues that may put the system at risk of not meeting relevant regulations governing used fuel and high-level waste handling

EPRI will ensure work conducted as part of this program is published in the open literature to the maximum extent possible, via EPRI reports and other publications.

The second prong of the project encompasses joint R&D work with participants in the Extended Storage Collaboration Program. For example, a high-burnup used fuel demonstration program has been proposed by many of the program participants, including many of the regulators. Other joint R&D project opportunities include the development of nondestructive evaluation techniques to assess the integrity of the stainless steel canisters for used fuel and high-level waste and the development of industry procedures for replacing aging storage systems as necessary.

Impact

Lack of disposal facility. The key driver is anticipated delays in the availability of ultimate disposition solutions for used fuel, whether it’s reprocessing or disposal. Even for those countries using reprocessing, the high-level waste glass canisters will likely need to be stored for a long period as well. At the end of the storage period, it will be necessary to transport the used fuel or high-level waste to the next phase in ultimate waste disposition (for example, reprocessing or disposal for used fuel; disposal for HLW). Safety functions for both long-term storage and ultimate transportation will need to be maintained for however long the initial storage period lasts. Some organizations, such as the U.S. Nuclear Regulatory Commission, are interested in assessing storage options for periods of up to 300 years. The continued use of existing storage systems could minimize financial costs and worker dose compared to having to repackage used fuel and high-level waste into new storage systems.

Transportation. The expanding use of high-burnup fuel raises issues with respect to transportation. Several regulatory organizations are concerned that the mechanical behavior of high-burnup used fuel may be less robust than that of lower-burnup used fuel. Data related to high burnup used fuel behavior in storage and transportation will be required as part of establishing the technical bases for extended storage.

Global relevance. Long-term used fuel and high-level waste storage is truly a global issue. Multiple organizations throughout the world have initiated or are planning to initiate R&D related to demonstrating safety of long-term storage followed by transportation. Sharing information and working together provides a collaborative approach for addressing the technical challenges confronting used fuel and high-level waste storage.

How to Apply Results

If very long-term dry storage followed or preceded by transportation is to be achieved to support potential changes in the long-term nuclear power program, it will be necessary to establish technical bases for the following:

- Wet and dry storage of lower-burnup used fuel beyond 60 years
- Wet and dry storage of higher-burnup used fuel beyond 20 years, preferably beyond 60 years
• Transportation of lower-burnup used fuel after very long-term storage
• Transportation of higher-burnup used fuel and HLW at all time periods

In addition to establishing these critical technical bases, this project will result in the development of nondestructive evaluation techniques for assessing the integrity of the stainless steel canisters into which both used fuel and high-level waste are placed. Finally, recognizing that aging storage systems may need to be replaced at some point in time, the project also intends to develop a set of procedures guiding such replacement.

Fuel Works/Cask Loader User's Group (supplemental) (052410)

Key Research Question
Fuel pools at many nuclear power plants are near capacity. While some used fuel can be stored outside the reactor building on concrete pads, the data needed to load used fuel into dry casks are often in disparate locations, and some are not in electronic form. A software program containing the necessary data to meet plant and cask vendor technical specifications is needed to choose fuel that would meet the specifications in the cask's Certificate of Compliance.

Approach
This project provides a mechanism for continued development, maintenance, and sharing of lessons learned regarding the Cask Loader software package. Cask Loader provides a tool for loading dry storage casks that enables plant personnel to minimize the need for fuel movement and significantly reduce documentation errors. Cask Loader helps select the appropriate used-fuel assembly for each cask and then prints the utility move sheets and other required forms.

Impact
Potential benefits from this project include the following:
• Optimize cask loading for cost and schedule
• Maintain data for Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) reporting
• Interact with cask vendor models and technical specifications
• Ease crowding in used fuel pools
• Mitigate personnel concerns on efficiency and dose
• Import current utility data and obtain reports in utility-specific format
• Facilitate easy updates for new utility or regulatory requirements
• Allow customization of new cask vendor and reports
• Perform gamma and neutron calculations
• Perform decay heat calculations based on Reg. Guide 3.54 (default) or NRC Branch Technical Position ASB 9-2

How to Apply Results
Members input data into Cask Loader from spreadsheets or ShuffleWorks files. The data include bundle/assembly as-built data, exposure, core location, and failure status; core data, including cycle dates and exposures; and cask data including as-built data. Cask Loader populates the chosen casks based on cask technical specification requirements and fuel available that meet the requirements of the cask. Members may choose to replace automatically chosen bundles with other candidates from the candidate pool. Reports can be printed and data output to spreadsheets or other proprietary report formats.
Nondestructive Evaluation Program (QA)

Program Overview

Program Description

Nuclear plant components and materials can undergo substantial changes in a nuclear environment. Plant owners must remain attuned to these changes to ensure steps can be taken if necessary to avoid unsafe operations or minimize mitigation costs. Nondestructive evaluation (NDE) is an important tool for assessing component condition, but depends on the availability of qualified technologies, personnel, and procedures.

The Nondestructive Evaluation Program develops technologies and procedures to quickly, accurately, and cost-effectively inspect and characterize nuclear component condition and inform strategic decisions on whether and when to replace, repair, or continue operation. Research results also are used to inform regulatory actions related to pre-service and in-service inspections and to support industry efforts to expand and accelerate the supply of qualified NDE workers in the nuclear industry.

Research Value

Research results from the Nondestructive Evaluation Program enable the accurate deployment of advanced inspection technologies to the nuclear power industry. Program activities also support the use of performance-based and risk-informed methodologies to improve inspection reliability. Collectively, these activities increase the accuracy of information related to material condition, potentially leading to lower operating costs, lower radiation exposure to workers, and an enhanced ability to meet regulatory commitments. NDE Program participants gain access to the following:

- Strategic roadmaps outlining research gaps confronting key issues—such as remote visual inspection, the soundness of concrete structures, and NDE of cast stainless steel—and the collaborative actions needed to address these gaps
- NDE technologies, training, and regulatory/code support that can shorten plant outages, leading to savings of $1 million or more per plant per day saved
- Technical analysis relating to the use of NDE diagnostic capabilities during extended plant operation, informing regulatory approval of license renewal or extension
- Implementation support for inspection and evaluation guidelines promulgated through the Electric Power Research Institute (EPRI) and industry materials analysis programs
- Qualification process for NDE personnel, procedures, and equipment in accordance with American Society of Mechanical Engineers (ASME) Section XI, Appendix VIII, and other qualification regimes adopted by industry
- Technical guidance supporting code changes that can lead to improved pre-service and in-service inspections
- Strengthened NDE workforce through focused training and central qualification resources

Approach

The Nondestructive Evaluation Program develops and demonstrates cost-effective and reliable inspection methods and analysis programs that can be integrated with structural and lifetime evaluations of power plant components and systems. NDE results contribute to more accurate characterization of nuclear component condition and help inform decisions on whether to replace, repair, or continue operation.

There are both base and supplemental components of the NDE research program. The base portion focuses on developing more efficient and more accurate NDE devices and techniques. Recognizing that staying ahead of materials issues requires sustained R&D, the program addresses NDE of all major plant components, including piping, vessels, balance-of-plant, and reactor internals. A wide range of NDE technologies are being evaluated, including ultrasonic guided-wave, low-frequency phased arrays, and laser-based technologies. Emerging
materials issues also are being investigated, including buried pipe, cast stainless steel, concrete civil structures, and spent fuel pools. Research results are primarily delivered as technical reports or guideline documents that are used by nuclear plants and their inspection vendors to develop safe, effective inspection strategies.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate, and execute needed research among multiple entities. For the NDE Program, roadmaps have been developed in four areas: concrete, remote visual inspection technology, NDE of cast stainless steel, and the development of a modeling and simulation center to support advanced NDE. This expansion of the NDE Program provides a single source solution for all NDE research activities. Two additional roadmaps on NDE reliability and NDE in support of new plant deployment are planned for 2011. Additional roadmaps will be developed as conditions warrant.

The supplemental portion of the NDE Program supports two main efforts: technology transfer and NDE reliability. Technology transfer is achieved largely through the evaluation and application support of NDE technologies to field-deployable products. NDE reliability is achieved through projects targeted at maintaining compliance with industry NDE requirements, including the operation and maintenance support of the Performance Demonstration Initiative, through which NDE personnel, procedures, and equipment are qualified in accordance with ASME Section XI, Appendix VIII.

**Accomplishments**

EPRI’s Nondestructive Evaluation Program supports nuclear industry efforts to address emergent material-and-inspection-related issues through innovative NDE technologies, technical guidance, and qualification support.

- Developed a buried piping NDE test facility. The test facility’s first installation is a 220-foot run of 24-inch piping containing several elbows and controlled defects. It will be used both for technology development and for NDE vendor capability benchmarking.
- Produced a reference guide for NDE techniques applicable to underground piping and tanks. Drawing on techniques in use outside the nuclear industry, the guide documents a variety of inspection techniques, their capabilities, and inspection gaps related to nuclear plant application.
- Developed a reference manual regarding the state of the art in managing aging concrete containment buildings, cooling towers, spent fuel pools, and other structures. The report reviews the performance history of these structures, introduces materials degradation mechanisms, and describes existing NDE methods.
- Successfully pilot-tested a risk-informed repair/replacement activity methodology (RI-RRA) and received regulatory approval from its use. The methodology allows plants to replace low-safety-significant components with commercial components rather than N-stamp components. Because ASME Section XI requirements would no longer apply, cost reductions of 3-10 times are expected.
- Published guidance for planning and executing efficient, effective examinations of dissimilar metal welds. Guidance was published publicly so that NDE vendors and utilities could collaborate to achieve greater success.
- Evaluated three-dimensional laser profilometry as a tool for generating more accurate surface contour profiles, which can provide unprecedented detail and sharply reduce the time required to make critical measurements. This first-of-a-kind application in the nuclear industry was field tested at several nuclear plants with favorable results.
- Published a report documenting the performance of a selection of digital radiography and computed radiography imaging systems, which have the potential to provide significant benefits over conventional film radiography in many inspection applications.
- Completed the first qualification for ultrasonic examinations of pressurized water reactor (PWR) vessel head penetrations. Although the qualification process was difficult, it achieved its main objectives before the aggressive regulatory deadline.
- Evaluated the use of guided wave ultrasonics and alternating current field measurements for inspecting spent fuel pool liner welds. If undetected, leaks from these welds could lead to contamination of groundwater and surrounding soils.
Current Year Activities

Nondestructive Evaluation Program research and development for 2012 will address a number of nuclear component materials issues where effective NDE is essential. Specific efforts will include the following:

- Conduct NDE modeling and simulation activities to enable efficiency improvements in ongoing NDE research and development projects
- Apply data from NDE qualification activities to demonstrate NDE reliability
- Deploy a first-of-a-kind NDE concrete laboratory for the nuclear industry
- Identify and characterize best practices for examining buried piping
- Maintain NDE qualification programs for compliance with regulatory and other industry commitments
- Convert risk-informed programs to applicable engineering code standards

Selected NDE program activities are conducted in whole or in part in accordance with Title 10, Code of Federal Regulations, Part 50, Domestic Licensing of Production and Utilization Facilities (10CFR50), Appendix B, Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants, and may invoke Part 21, Reporting of Defects and Noncompliance (10CFR21). Additional NDE program activities may be conducted in accordance with 10CFR50 Appendix B and 10CFR21 at the discretion of the Nondestructive Evaluation Center, member utilities or EPRI, when such action is deemed appropriate.

Estimated 2012 Program Funding

$17 million

Program Manager

Greg Selby, 704-595-2595, gselby@epri.com

Summary of Projects

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<td>Concrete Structures (Roadmap) (QA)</td>
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<td>NDE Modeling and Simulation Center (Roadmap)</td>
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<tr>
<td>P41.04.01.05</td>
<td>Nondestructive Evaluation Applications and Technology (QA) (supplemental)</td>
<td>The Nondestructive Evaluation Applications and Technology Transfer project develops products that support the demonstration, qualification, and technology transfer of NDE technology to field-useable products and services.</td>
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<tr>
<td>P41.04.01.06</td>
<td>Performance Demonstration Training and Qualification (QA) (supplemental)</td>
<td>This project provides general operation and maintenance support of the Performance Demonstration Initiative (PDI) program. Through the PDI program, utilities and their service providers, NDE personnel, NDE procedures, and equipment are qualified in accordance with ASME Section XI, Appendix VIII.</td>
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### Assessment of CAST Stainless Steel (Roadmap) (QA)

#### Key Research Question

Cast austenitic stainless steel (CASS) materials are prevalent in many safety-related nuclear power plant components, including the primary coolant piping system in pressurized water reactors. CASS components also are currently being designed for new power plant construction. The long-term performance of this material, however, is not well understood. Volumetric examination of cast stainless steel piping is required, but no reliable nondestructive evaluation (NDE) techniques exist. In addition, a comprehensive model to determine the maximum allowable flaw size for CASS is not currently available. These gaps also have raised concerns with regulators and licensees. A comprehensive strategy for assessing CASS materials is needed that includes the development of reliable NDE techniques or an alternative approach for continuing the use of CASS materials.

#### Approach

Research regarding examination of cast austenitic stainless steel components will result in the identification of the most effective technologies for inspection. The assessment of CASS includes the following major activities:

**Resources:**
- Collaborate with utilities worldwide to obtain information regarding lessons learned and operating experiences involving CASS components
- Procure representative cast austenitic stainless steel mockups for industry activities
- Benchmark global NDE inspection capability and reliability
- Investigate the underlying reasons for insufficient results when inspecting CASS with existing volumetric examination tools to allow breakthroughs in developing the next generation of inspection tools

**Technology Modeling:**
- Perform mechanistic studies on thermal aging of CASS and investigate crack initiation and propagation behavior in representative CASS materials
- Prioritize the CASS components of most concern and determine the critical flaw size based on the material composition and environment
- Develop and investigate computer models to simulate the material characteristics for CASS and the impact to NDE methods
- Utilize mathematical modeling to further the understanding of the challenges surrounding volumetric examination of CASS

**Technology Transfer & Application of Results:**
- Develop NDE practices for the inspection of cast austenitic stainless steel components
- Measure the reliability of the newly developed techniques through physical trials and simulation
- Document capabilities in reports and procedures that can be transferred to vendors and utilities for field use
- Host working group meetings, conferences, and round robins for researchers, inspection services vendors, and utilities
- Transition the research into the initiation of a performance demonstration program to determine specific examination procedure capabilities and then transfer inspection technologies for field use
Impact

Equipment Reliability: The ability to provide a reliable assessment of CASS materials will be essential for life extension and license renewal activities. There remains a level of concern with cast austenitic stainless steel components because of the possibility of thermal embrittlement over time and the limitations of current volumetric inspection techniques. Establishing a robust aging management approach for CASS components exposed to reactor coolant environments is currently constrained by a lack of data, operating experience, and proven NDE solutions.

Regulatory: Globally, regulators continue to push for technique improvements for examining cast austenitic stainless steel. Section XI of the ASME Boiler and Pressure Vessel Code requires that the pressure boundary system of light water reactors be inspected using a volumetric technique. Meeting this requirement is very challenging for cast austenitic stainless steel piping due to the material’s microstructure. The currently specified examination methods have proven to be unreliable in numerous studies performed at EPRI and other research facilities.

New Construction: Regulators have advised that relief from performing examinations of new components prior to service will not be accepted for the new build. As a result, the industry needs to address and overcome CASS inspection challenges to support the licensing, manufacturing, and operation of new power plants.

How to Apply Results

The completion of this work is expected to result in the following:

- A probabilistic fracture mechanics tool to determine the critical flaw size for cast austenitic stainless steel components will be developed. A quantitative model of CASS materials performance based on the understanding of its resistance to embrittlement and cracking will be available.
- A method will be available for determining the presence and severity of thermal aging of cast austenitic stainless steel materials in-situ and a timeline will be established for when a safety issue may need to be addressed. An investigation of the severity of thermal aging embrittlement in CASS should identify which weldments are susceptible to more rapid crack growth.
- An approach to efficiently map the grain structure of the CASS material for subsequent examination technique enhancements will be accessible. Utility members will have access to computer models to better characterize the cast austenitic stainless steel components in their plants.
- Cast austenitic stainless steel mockups will be available for industry use in training, research, and qualification activities.
- A risk-informed inspection methodology to minimize the number of required examinations will be developed.
- NDE methods optimized for cast austenitic stainless steel examination will be available to provide more reliable results to the utilities.
- A technical basis for determining the integrity of cast austenitic stainless steel components will be established by which regulators can use to assess available NDE technologies.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Concrete Structures (Roadmap) (QA)

Key Research Question

The degradation of concrete can challenge the safe, efficient, cost-effective operation of electric power generation facilities. At nuclear power plants, some concrete structures are being operated beyond their originally intended service lives, driving the industry to address degradation mechanisms previously deemed not severe enough to limit plant life. Because such structures are typically either expensive or considered impossible to repair, a long-term strategy for asset management is needed.
Adequate tools do not exist to characterize the integrity of existing and new concrete structures and to predict their remaining life. Improved nondestructive evaluation (NDE) techniques are needed to confidently assess structural integrity, as are certification processes and protocols to ensure their reliability.

**Approach**

This project is based on a thorough knowledge of materials degradation applied to individual structures. Material degradation is identified in-situ through inspection. Reliability and development of improved characterization technologies will be addressed through a focused effort on overcoming the challenges of concrete structures in this industry, typically characterized by large structures with heavy reinforcement and a lack of accessibility. Finally, an asset management platform will be developed for concrete structures for the particular environment where concrete structures are located.

At a later stage, a parallel effort will be initiated on new infrastructure materials (for example, modular steel-concrete construction). This new effort will follow a similar path as with existing concrete structures, with an ultimate goal to develop an asset management platform for the particular environment where these new structures are located.

The synergy between different energy sectors will be used to benefit this program. For example, the existence of similar concrete structures in coal plants, but with a different regulatory environment, may make it easier to start implementing new inspection techniques in the fossil industry prior to their implementation in nuclear plants.

**Impact**

Public perception—Public perception and acceptance of nuclear plants could diminish because of visible degradation of large and highly visible concrete structures or partial failures of other structures.

Asset management—Many utilities will need to budget for major repairs or replacements of large concrete structures. Thorough inspection will be required to diagnose an estimated remaining life.

Long-term operation—The economic basis for long-term operation requires technical information regarding the structural soundness of plant systems and components, including concrete facilities. Structures such as concrete containment, basements, and spent fuel pools cannot be replaced and can limit the service life of the plants.

Regulatory requirements—Regulatory bodies may increase scrutiny of concrete structures in defining requirements for life extension or license renewal.

New construction—Technology gaps related to new infrastructure have already delayed construction activities at some new plant projects. These gaps should be addressed to inform technical decisions for subsequent waves of new plant deployment.

Limitations of inspection technology—The NDE methods and structural assessment methods currently available cannot provide the level of reliability required for existing and new nuclear plants and demanded by stringent regulatory requirements. A system to accommodate rapid NDE test deployment, identification of damage, and implementation of repair techniques would enhance the assessment of emerging issues in older plants.

**How to Apply Results**

The completion of this work is expected to result in the following:

- All sectors of the electricity industry (nuclear, generation, transmission and distribution) will have access to best practices related to infrastructure asset management and inspections.
- Utilities will be able to deploy improved and reliable NDE tests to assess emergent and routine degradation of concrete infrastructure.
• Utilities will have an asset management platform for concrete infrastructure where the rate of degradation can be predicted and repairs, maintenance, and replacement needs can be identified early and planned in advance.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Remote Visual Examinations (VT) (Roadmap) (QA)

Key Research Question

The nuclear industry relies heavily on the use of remote visual examination (VT) for assessing reactor pressure vessel internals and related components. However, the flaw detection capabilities and limitations of remote VT are not well understood, and global regulators continue to question the robustness and reliability of remote VT. It is anticipated that additional regulatory actions are likely to mandate qualification of remote VT in the future. Some countries in Europe have already implemented such requirements. Widespread implementation of reliability requirements for remote VT could result in significant additional costs for personnel training and qualification, impact resources that are already constrained, and potentially increase inspection time, radiation dose, and outage duration. Better understanding of the reliability of remote VT is needed to inform regulatory consideration of this technology.

Approach

The following research and engineering activities are proposed to assess the reliability of remote VT technology for continued use in in-vessel examinations:

• Conduct parametric studies of remote VT process variables (for example, distance, angle, lighting, use of zoom, length sizing) to fully characterize the relationship of these variables to flaw detection.
• Perform engineering analysis to develop acceptance criteria, determine critical flaw sizes (lengths), and define the relationship between crack opening dimension and flaw evaluation criteria.
• Benchmark global remote VT technology and research activities, including technical support of industry remote VT round robins and qualification programs.
• Refine flaw design and fabrication processes for fabrication of remote VT test specimens.
• Develop training materials for utility and examination personnel on Boiling Water Reactor Vessel Internals Project (BWRVIP) and Materials Reliability Program (MRP) internals inspection guidelines and remote VT best practices.
• Assess technology gaps and research improved remote VT techniques and processes. Evaluate advanced NDE technologies that may be used as alternatives to remote VT.
• Evaluate the potential effects on the nuclear industry if qualification of remote VT is required.
• Facilitate technology transfer of research results and new technologies to equipment manufacturers and service providers.

Impact

The main drivers for a strategy on remote visual examinations include the following:

1. Regulatory Impact—Regulators worldwide have expressed concern regarding the adequacy of remote VT implemented without system qualification. Precedent has been established to qualify remote VT procedures and personnel. Research is needed to assess the viability of rigorous qualifications for remote VT.
2. Aging Management Program Integrity—The nuclear industry relies on remote VT for assessing reactor pressure vessel internal component integrity to satisfy inservice inspection (ISI) requirements and aging management program commitments. If the current implementation of VT is deemed inadequate, there could be adverse effects on implementation of industry inspection and evaluation guidance. Alternative examination methods may be required or stop-gap qualification programs implemented.
3. State of Knowledge—The current state of knowledge into understanding the capabilities and limitations of remote visual examination is not sufficient to adequately address regulatory concerns about reliability. Regulators continue to question the reliability of remote VT and are conducting their own research to assess the capabilities of remote VT for flaw detection.

4. Lack of Flaw Evaluation Criteria—Flaw acceptance, evaluation criteria, and critical flaw sizes (lengths) have not been adequately defined for many internals components. Coupling the lack of acceptance criteria with an insufficient understanding of the capabilities and reliability of remote VT results in uncertainties in assessing the structural integrity of internals components.

How to Apply Results

This project will develop the information necessary to establish the capability and reliability of remote VT for the detection of structurally significant flaws in BWR and PWR internals components. Utilities and their service providers will use this technical basis in discussions with regulators to assess the reliability of remote VT techniques and procedures.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

NDE Modeling and Simulation Center (Roadmap)

Key Research Question

Inspection needs for certain nuclear plant applications are too complex for current nondestructive evaluation (NDE) technologies. Regulatory and industry commitments require validated solutions, but traditional approaches to validation are costly and time-consuming. Modeling and simulation technology can potentially replace and/or augment physical development and testing.

Approach

The development of the EPRI global modeling center of excellence plan is defined in four phases:

Scoping
Develop a precise understanding of global needs, both present and future, on issues such as cast stainless steel, buried pipe, long-term operation, and license renewal. Coordinate with regulators to understand their expectations for modeling and the criteria by which it would be accepted in lieu of physical demonstration. Explore collaborations with other institutes and universities. Perform a global survey of modeling and simulation tools available today. Deliverable: gap analysis.

Equipping
Specify and contract development of new models as needed per the gap analysis. Acquire the necessary workstation clusters and software. Equip a modeling and simulation laboratory in the EPRI Charlotte facility and worldwide satellite laboratories. Identify and acquire resources. Develop model benchmarking and validation plan, with appropriate coordination with regulators. Deliverable: equipped Modeling and Simulation Center.

Ramping Up

Operation
Finalize benchmarking and validation. Finalize integration while developing NDE solutions to respond to membership needs. Continue benchmarking and collaborations.
Deliverable: operational Modeling and Simulation Center.

Impact

Economics—Physical demonstrations of NDE techniques are expensive. Development of a new qualification program relying wholly on practical demonstration can cost several millions to tens of millions of dollars. Mockups can cost $100,000 to $1 million each and take years to build. Failed empirical trials impact cost and schedule.

Human Performance—There have been several incidents of false calls resulting from qualified examiners' lack of experience with field situations. Additionally, an NDE workforce gap is projected. Although efforts are in place to bring new personnel into the workforce, workers will need focused training to prepare for the qualifications and for the field inspections. Modeling can be used as a training tool to bring understanding to the inspector of the complex inspection challenges associated with the component.

Reliability—An NDE probability of detection (POD) is required for condition assessment and asset management. Physical demonstration often includes personnel testing to establish inspection system capability in terms of POD; modeling can be used to predict those results in lieu of costly performance demonstration testing. Additionally, high NDE reliability is needed to reduce false calls.

Regulatory—The requirements for inspection technique demonstration are increasing in virtually every nuclear nation. Theoretical justification through modeling is now a standard requirement in many countries and is recognized as an acceptable way of meeting the requirements for NDE qualification and performance demonstration (European Network for Inspection Qualification guidelines and ASME Section V/Article 14 requirements). With new qualification programs possible in several areas (for example, welds in new plants, buried piping, PWR and BWR internals, concrete, cables, and visual examinations), theoretical justification via modeling could ease implementation.

How to Apply Results

The completion of this work is expected to result in the following:

- Coordination of industry models will provide utilities with a suite of tools to address NDE issues and provide solutions
- Regulatory bodies will have increased confidence in theoretical approaches to validating NDE solutions
- Universities, research institutes, utilities, and vendors will have an integrated approach to modeling and simulation
- The nuclear industry will realize improvements in human performance through better training and understanding of NDE capability
- Other sectors such as generation and renewables will have a basis to implement modeling in lieu of physical demonstration

Nondestructive Evaluation Applications and Technology (QA) (supplemental) (068025)

Key Research Question

Nondestructive evaluation (NDE) capabilities address a number of nuclear power industry needs, including preservice and periodic in-service inspection of components to satisfy regulatory requirements, inspection to characterize component condition, and inspection to guide strategic decisions on whether and when to replace, repair, or continue operation of components. The nuclear power industry must remain cognizant and receptive to the introduction of new technology while ensuring confidence in the overall reliability of the NDE processes employed. Often, the industry requires technical assistance to support the implementation and effective application of advanced NDE technologies.
Approach

The NDE Applications and Technology program provides the nuclear power industry with a collaborative “ready now” NDE resource focused on today's operations and emerging issues. A team of more than 40 EPRI NDE technical staff target nuclear power applications and enable NDE technology transfer through the following activities:

- Inspection strategies and application plans using the results from the EPRI NDE research and development program
- Regulatory and code support for pre-service and in-service inspections
- Evaluation of NDE technology to address aging plant and equipment reliability issues
- Resources to facilitate the supply of qualified NDE workers in the nuclear industry
- Supporting member utilities with independent assessments of NDE technology and results

Impact

NDE Applications and Technology Transfer program participants benefit from the development and application of NDE hardware, software, databases, and methods. These products include technical services support to participating nuclear units, as well as technical support to other EPRI Nuclear programs, including the Performance Demonstration Initiative (PDI), materials programs (Materials Reliability Program [MRP], Boiling Water Reactor Vessel and Internals Project [BWRVIP], Steam Generator Management Program [SGMP]), Low-Level Waste, Balance of Plant Corrosion, Advanced Nuclear Technology, and Fuel Reliability.

How to Apply Results

The results of the NDE Applications and Technology Transfer program are provided through EPRI technical reports and guidelines that member utilities directly apply. In some cases, program participants may elect to apply the results via service organizations that provide in-service inspection and other related inspection services. Participants also apply the results of the program through collaborative resources such as NDE mock-ups and generic procedures. Indirect methods of application also are used, including technical changes to inspection codes, NDE training materials for participants and their suppliers, and the release of good practice documents targeting increased public awareness and confidence in the reliability of NDE.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Performance Demonstration Training and Qualification (QA) (supplemental) (061738)

Key Research Question

Revisions to 10CFR50.55(a), initially published September 22, 1999, mandate the implementation of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, Division 1, Appendix VIII, Performance Demonstration for Ultrasonic Examination Systems. Appendix VIII requires qualification of the procedures, personnel, and equipment used to detect and size flaws in certain piping, bolting, and reactor pressure vessel components.

Approach

This program includes the general operation and maintenance of the Performance Demonstration Initiative (PDI) program. This includes quality assurance (QA) activities, document control, and database maintenance.

Impact

The PDI program is administered by EPRI to address the requirements of the ASME Boiler and Pressure Vessel Code, Section XI, Division 1, Appendix VIII, in a collaborative, efficient, cost-effective, and technically sound manner.
How to Apply Results

Results of the PDI program may be applied by member utilities and organizations that provide in-service inspection services as defined in the PDI use agreement. Additional information on the application of the results is available at www.epriq.com.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Nondestructive Evaluation Research and Development (base) (QA) (068030)

Key Research Question

The existing nuclear fleet has a proven track record of operating safely and effectively. Extending this track record will depend on continued, reliable insight into the condition of materials to assess and address aging and degradation. Nondestructive evaluation (NDE) plays a vital role in managing material aging issues. In recognition of this increasing role, EPRI conducts NDE research and development to develop NDE solutions that assist the nuclear power industry in safely operating and maintaining existing nuclear assets.

Approach

The Nondestructive Evaluation (NDE) Research and Development program focuses on developing more efficient and more accurate NDE devices and techniques. Staying ahead of materials issues requires sustained R&D. The program addresses NDE of all major plant components, including piping, vessels, balance-of-plant, and reactor internals. Emerging materials issues also are being tackled, including buried pipe, cast stainless steel, civil structures, and spent fuel. A wide range of NDE technologies are being evaluated, including ultrasonic guided-wave, low-frequency phased arrays, and laser-based technologies.

R&D activities employing the latest NDE techniques including modeling and simulation technologies will address a variety of challenging materials inspection issues:

- Buried components
- Cast stainless steel
- Civil structures and materials
- Reactor vessel internal components
- Spent fuel pool and transfer canal liners

Impact

- Inspection strategies targeting existing and emerging degradation issues
- New inspection technologies for buried pipe, concrete, and cast stainless steel
- NDE approaches that facilitate life extension

How to Apply Results

The results of the NDE Program are primarily delivered as technical reports or guideline documents that are used by utilities and their inspection vendors to develop inspection strategies. Additionally, the results of the NDE Research and Development Program are often used as the technical basis for generic inspection strategies and procedures.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.
Nuclear Maintenance Application Center

Program Overview

Program Description

Maintenance practices at nuclear power plants play a critical role in a unit’s ability to achieve or maintain high reliability and capacity factor levels. To this end, maintenance practices must be continuously reviewed and updated based on industry operating experience and emerging issues. The Nuclear Maintenance Application Center conducts research to identify maintenance advances with the potential to produce substantial plant performance improvements. These activities require accurate assessment of plant needs and tend to be strategic, complex, and longer in duration.

The Nuclear Maintenance Application Center develops maintenance guides and coordinates worldwide technology transfer to drive improvements in nuclear maintenance activities. The program’s technical guides, user groups, and workshops reflect best practices and engineering judgment gathered from nuclear plant experience, providing actionable maintenance activities that lead to lower costs and higher reliability.

Research Value

Research results from the Nuclear Maintenance Application Center provide knowledge and guidance that enable nuclear plants to reduce operations and maintenance costs and improve equipment reliability. Participants gain access to the following:

- More than 250 maintenance guides for nuclear equipment and systems, which provide source documents for improved procedures and training packages
- A worldwide network of maintenance professionals to help resolve nuclear plant maintenance issues
- Quicker identification of failure-related root causes through the use of a telephone hotline, program staff, and other program participants
- A broader range of maintenance solutions with reduced implementation risks due to collaboration with subject matter experts from all over the world
- Templates for establishing defensible preventive maintenance practices and intervals for key components and systems
- Industry data and best practices from more than 30 plant visits each year, providing lessons learned for implementing maintenance program improvements

Approach

The Nuclear Maintenance Application Center conducts near-term and long-term research to drive maintenance improvements at nuclear plants. Long-term research focuses on new methods and approaches that drive sustained improvements to plant equipment, processes, and practices. Near-term research focuses on maintenance methods and guidance that can help reduce operations and maintenance costs and improve equipment reliability.

There are both base and supplemental components of the Nuclear Maintenance Application Center Program.

Base research focuses on developing maintenance program improvements that can increase equipment reliability and plant performance and on developing and implementing new processes and technologies that can close the gaps between current issues and available solutions.

- Equipment Issues and Maintenance Guides: Maintenance strategies, fully informed by operating experience and technology advances, can result in improved equipment reliability, lower operating costs, and higher overall plant reliability. This program area identifies and addresses important maintenance and equipment issues by conducting more than 30 plant visits each year and compiling data from vendors, the
Institute of Nuclear Plant Operations, and other industry sources. The project develops guides to aggregate relevant diagnostic and mitigating technical advice for addressing key maintenance issues. These guides include problem identification, troubleshooting information, preventive and predictive maintenance advice, and detailed maintenance tasks.

- **Operations and Maintenance Procedures**: Bringing essential information to the point of decision-making can drive safe and reliable plant and fleet performance. Access to equipment information and personnel knowledgeable in operations and maintenance practices from outside one's immediate plant of company can provide useful perspective and input. In this program area, Electric Power Research Institute (EPRI) expertise is applied to plant operation and maintenance concerns through direct phone and email interaction, routine plant visits, assistance with selected plant assessments, and specific field response when emergent issues arise. EPRI staff also use this expertise to develop reports and guidelines that address new or improved methods and processes to enhance nuclear plant performance.

The supplemental portion of the Nuclear Maintenance Application Center Program provides access to a larger population of maintenance and process guides, as well as a range of user groups targeting solutions to issues related to specific equipment, software, or regulations. The user groups provide a forum for exchanging information on topics such as circuit breakers, hoisting and rigging, electric motors, pumps, Terry Turbines, transformers, and switchgear.

Through separately funded supplemental projects, participants can receive expert EPRI support in implementing EPRI research results, including training, software implementation support, work package planning, and various maintenance assessments. Nuclear plants also can access targeted user groups on the Maintenance Rule, the Preventive Maintenance Basis Database, and EPRI's Motor-Operated Valve Performance Prediction Program.

**Accomplishments**

Electric Power Research Institute's (EPRI's) Nuclear Maintenance Application Center distills global operations and maintenance experience into actionable guidance for nuclear plant systems and components. Lessons learned from nuclear plants around the world are incorporated into industry- and vendor-specific technical guidance.

- Created a comprehensive web-based pump resource that enables nuclear plant operators to more easily access EPRI products related to pump maintenance and troubleshooting. The resource includes a nuclear industry pump database, pump repair specifications, and self assessment aids.
- Developed clearance and tagging guidelines that nuclear electric generating companies can use as a basis for comparison with their own programs. These programs serve to protect personnel from injury and to protect equipment from damage.
- Issued a single-source reference guide for implementation of best practices in grease lubrication, guidance for proper lubricant selection, and evaluation of available and emerging technologies and techniques to optimize lubrication effectiveness.
- Developed new or revised maintenance and process guides for key plant systems and equipment, including feedwater system, the generator portion of emergency diesel generators, oil lubrication systems, and heat exchangers.
- Evaluated alternatives to wire brushes for routine nuclear plant maintenance. Report recommends alternatives, with emphasis on tooling requirements, product speeds, temperature limitations, and brush applications.
- Updated EPRI guidance on nuclear plant fluid sealing programs to incorporate lessons learned from field experience. The update recommends a philosophical shift away from "fluid leakage" and toward "fluid sealing" that would integrate procedures, materials, training, and management support.
- Updated the Preventive Maintenance Basis Database (Version 2.1). This product enables utility engineers to readily access technically applicable and cost-effective preventive tasks.
Current Year Activities

Nuclear Maintenance Application Center (NMAC) Program research and development for 2012 will focus on updates to key equipment maintenance guides, greater outreach to domestic and international participants, and focused attention to emerging industry maintenance issues. Specific efforts will include the following:

- Develop the methodology to build the failure reasoner process.
- Develop end-of-life guidance for transformers. Compare paper samples taken from inaccessible areas (transformer hotspot) with paper from accessible areas (leads) of transformers undergoing rebuild or post failure evaluation to assess correlation of measured differential pressure to end of paper life.
- Determine basic seal design parameters and commercial viability of a seal using piezoelectric technology to improve seal performance and reduce maintenance.

Estimated 2012 Program Funding

$7.1 million

Program Manager

Martin Bridges Jr, 704-595-2672, mbridges@epri.com

Summary ofProjects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>P41.05.01.01</td>
<td>Preventive Maintenance Basis Database (supplemental)</td>
<td>The Preventive Maintenance Basis Database (PMBD) User Group serves as the primary source for input to guide new and revised functionality for the database. Members share experience with the database and suggest new component types that may need to be developed.</td>
</tr>
<tr>
<td>P41.05.01.02</td>
<td>Member Requested Support (supplemental) (QA)</td>
<td>NMAC offers assistance to members in evaluating the extent to which various NMAC products can provide value to their organization. Such assistance may include training, software implementation support, work package planning, and on-line maintenance assessment.</td>
</tr>
<tr>
<td>P41.05.01.03d</td>
<td>Maintenance Rule User Group (supplemental)</td>
<td>The Maintenance Rule Users Group (MRUG) provides a forum for information exchange between participants to resolve technical issues from baseline inspections and ongoing revisions to the maintenance rule. MRUG develops technical guides and compiles good practices that can reduce implementation costs, increase consistency among participants, leverage rule activities to improve plant performance, and reduce vulnerability to regulatory compliance issues.</td>
</tr>
<tr>
<td>P41.05.01.04c</td>
<td>Motor-Operated Valve Performance Prediction Methodology User Group (QA) (supplemental)</td>
<td>The EPRI MOV PPM User Group (EMPUG) provides ongoing code maintenance, user technical support, and training. EMPUG supports users of the EPRI MOV Performance Prediction Methodology and the EPRI MOV Performance Prediction Program.</td>
</tr>
</tbody>
</table>
Preventive Maintenance Basis Database (supplemental) (068039)

Key Research Question

Effective industry use of preventive maintenance strategies relies on widespread availability of component-specific maintenance data and information. A comprehensive repository of preventive maintenance basis information for power plant equipment can support effective maintenance. Feedback and dialogue among database users leads to functional improvements and more effective application.

Approach

The Preventive Maintenance Basis Database (PMBD) collects data from worldwide industry sources to develop a comprehensive repository of PM basis information for power plant equipment. The PMBD contains the data related to PM tasks, task intervals, and the technical bases of these tasks for all defined failure and degradation mechanisms. The foundation of this repository was the EPRI 38-volume *PM Basis Reports and Handbook* (TR-112500) and, subsequently, PM Basis Database Client /Server Version 2.0 and subsequent versions.

Impact

The PMBD User Group serves as the primary source for new or revised functionality of the database. User group members serve as the beta testers for new versions of the database. The group also will suggest new component types that may need to be developed, and the group will provide input on what interfaces should be developed for the database.

How to Apply Results

Members in the PMBD User Group receive copies of the current version of EPRI PM Basis Database containing information on the preventive maintenance programs recommended for 130+ component types. Updates to the existing component data tables and the addition of data tables for new component types will be communicated to members so they can download the new data as desired.

Member Requested Support (supplemental) (QA)

Key Research Question

Members are often challenged in applying NMAC products. Therefore, NMAC offers assistance to members in evaluating the extent to which these products can provide value to their organization.

Approach

Support services can include the following:

- Training
- Implementation of the Preventive Maintenance Basis Database
- Work package planning and preparation
- Foreign Material Exclusion (FME) program support
- Sealing technology and bolting techniques
- Implementation support in the area of on-line maintenance
- Specific component maintenance strategy support
- Expert assistance via evaluations and audits, or as consultants for resolving problems

NMAC provides on-site member-requested support to participating utilities on a cost recovery basis. The scope of member-requested support activities should be consistent with the overall objectives of the NMAC program. Examples of typical activities include programmatic and technical review of specific engineering programs, implementation of NMAC products, and response to a plant’s technical issues. The costs of these services vary, depending on the level of support requested.
Impact

Reduced engineering staffs, aging plants, and dwindling vendor and architect/engineer (A/E) support make solving engineering system and component problems more difficult for operating nuclear plants. In this environment, utility engineers need a variety of tools available to assist them with problem resolution. This program provides utility personnel with information and technology solutions that decrease the time and cost needed to resolve specific technical issues or implement specific programs or products. Improved decision-making is the greatest utility benefit delivered by this program.

How to Apply Results

This program will be delivered through on-site technical assistance. This program is offered in one-week increments of a full-time equivalent NMAC representative.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Maintenance Rule User Group (supplemental) (006893)

Key Research Question

The Maintenance Rule User Group (MRUG) develops solutions to generic technical issues associated with implementation of the maintenance rule. High-priority issues identified by MRUG members have included guidance on (a)(3) maintenance effectiveness assessments, guidance on component “run-to-failure” justification, and clarification of unavailability times for standby equipment. Feedback and dialogue among members can identify project opportunities to improve maintenance rule application.

Approach

The Maintenance Rule User Group provides an information exchange among participants through periodic meetings, newsletters, and website and email communications. Such information exchange between participants and EPRI helps resolve technical issues from baseline inspections and ongoing revisions to the rule. MRUG also develops technical guides and documentation of good practices that can reduce costs of implementation, increase consistency among participants, leverage rule activities to improve plant performance, or reduce vulnerability to regulatory compliance issues.

Impact

MRUG identifies best practices for issues such as balancing availability and reliability, monitoring of structures, improving timeliness of (a)(1) actions, coordination with the Equipment Performance Information Exchange (EPIX), and uses of condition monitoring for performance criteria. These efforts do not aim to commit plants to a single approach, but rather to identify cost-effective options, foster discussions on the strengths and weaknesses of the various options, and provide guidelines on their effective utilization.

How to Apply Results

Membership in MRUG allows plants to participate in the development of implementation guidance and to provide comments and feedback to the process.
Motor-Operated Valve Performance Prediction Methodology User Group (QA) (supplemental)
(004433)

Key Research Question

EPRI’s Motor-Operated Valve Performance Prediction Methodology (MOVPPM) provides a low-cost alternative to prototype (or in situ) design basis differential pressure testing of motor or air-operated valves. MOVPPM software (QA) validates the thrust/torque requirements under design basis flow and differential conditions of gate, globe, and butterfly valve designs commonly found in both motor and air-operated valve service. In addition to the code, several hand calculation methods have been developed to address specific designs not covered by the code. The methodology has been approved by the U.S. Nuclear Regulatory Commission. Feedback and dialogue among software users can lead to functional improvements and more effective application.

Approach

The EPRI MOV PPM User Group (EMPUG) provides ongoing code maintenance, user technical support, and training for the MOV Performance Prediction Methodology (MOVPPM) and the MOV Performance Prediction Program (MOVPPP). The users forum enables exchange of information pertaining to utilization of the methodology and a vehicle for maintaining and modifying the MOVPPM code.

Impact

Use of this methodology obviates the need for differential pressure testing either as an initial demonstration of or periodic verification of design basis capability. Not only does MOVPPM greatly decrease downtime for valve testing in general, it can significantly reduce valve failures due to insufficient torque or thrust.

How to Apply Results

MOVPPM is Windows™-based and runs on personal computers and comes with support documentation. Use of the method requires the utility to obtain valve internal design information from valve vendors, which requires about one man-week per valve.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.
Plant Engineering

Program Overview

Program Description

Safe, reliable, cost-effective nuclear plant operation is supported by detailed, technically sound engineering practices. Engineering analysis, for example, is important in assessing the condition of plant components and whether they should be replaced or repaired. Engineering also is critical when investigating life-limiting conditions, evaluating plant performance improvements, and assessing component and vendor quality.

The Plant Engineering Program performs research to support the long-term, cost-effective operation of the nuclear fleet, addressing key equipment issues and enhancing the effectiveness of plant engineering programs. Issues addressed include equipment/component reliability, product and vendor quality, cable aging, buried piping, flow-accelerated corrosion, workforce and skills development, life-cycle management, and obsolescence. The program also supports technology transfer through technical assistance programs, training, and user group workshops.

Research Value

Research results from the Plant Engineering Program provide engineering-based guidance that enables nuclear plants to improve equipment reliability and reduce operations and maintenance costs. Participants gain access to the following:

- Strategic roadmaps outlining research gaps confronting key issues—such as cable aging and underground pipe integrity—and the collaborative actions needed to address these gaps
- Definitive cable condition assessment methods that enhance the ability to identify, assess, and manage aging
- Enhanced validation of procured item quality and improved procurement specifications to reduce procurement costs, solve obsolescence issues, and define needed engineering process changes
- Improved long-term planning on key components to avoid in-service failures and potential plant outages
- Enhanced workforce skills development tools to address gaps in utility training programs, validate worker skills prior to use, and facilitate worker movement between sites
- Technical results enabling the use of high-density polyethylene pipe as a replacement option for degraded metal pipe
- Risk-ranking software and inspection and mitigation technology to characterize and address buried pipe and buried pipe coating degradation
- Inspection and mitigation technologies for components susceptible to flow-accelerate corrosion

Approach

The Plant Engineering Program investigates engineering process improvements to more effectively inform and respond to plant, system, and component issues. The program targets issues such as unanticipated material degradation deficiencies that can reduce the inherent design margins in plant equipment and impact equipment reliability.

Base research encompasses equipment reliability, engineering processes, procurement, vendor quality, balance-of-plant corrosion, and workforce skills development.

- Equipment Reliability and Engineering Processes: Sustained equipment reliability at nuclear plants depends on attention to both near-term and long-term degradation mechanisms that can lead to failure, unacceptable performance, or premature replacement. This project develops guidance on generic and specific aging issues to support emergent and end-of-life component decisions. Both theoretical and practical guidance is developed, including aging models, data, and acceptance criteria for components
and cable; field guides for walkdowns and inspections; condition-monitoring techniques; and sourcebooks for gauging end-of-expected life.

- **Procurement and Quality Issues:** Procured item quality issues have negatively impacted plant reliability and costs for replacement items. Causes of poor product quality include loss of vendor expertise, lack of vendor understanding, and poor specification development. This research area consists of three elements: 1) Continued support of forums for sharing procurement-related concerns and experience through the Joint Utility Task Group and Nuclear Supply Chain Strategic Leadership Council; 2) Research on the root cause and corrective actions to enhance vendor quality, common procurement specifications, source surveillance templates, and guidance on detecting fraudulent and counterfeit items; and 3) Prioritization and management of obsolete items, including a pilot project to demonstrated methods being developed.

- **Workforce Skills, Knowledge and Assessment:** Substantial nuclear plant personnel turnover in the next 5-10 years will result in widespread training of new personnel to continue operating existing plants safely and to support new plant construction and operation. Moreover, the availability and skills level of supplemental workers for power plant outages is less certain. Computer-based training can improve the effectiveness of engineering training and reduce the associated costs. Plant Engineering has developed computer-based training for nine engineering fundamentals topics. For supplemental workers, EPRI continues to develop knowledge exams and skills proficiency demonstration exams that can be administered to verify skills competencies and make such competencies portable.

- **Balance-of-Plant Corrosion:** Corrosion in the secondary system of nuclear plants can negatively impact plant reliability and can result in annual costs of up to $25 million per plant related to flow-accelerated corrosion, degradation of service water systems, and degradation in raw water heat exchangers. Through guidance for effective underground piping programs, risk-ranking software, flow-accelerated corrosion, and interactive communications, this research area develops tools for addressing corrosion issues and improving the service life of balance-of-plant piping and components. This research area also investigates alternatives to steel pipe, such as high-density polyethylene, and develops improved inspection techniques for assessing the health of piping systems.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate, and execute needed research among multiple entities. For the Plant Engineering Program, roadmaps have been developed to address cable aging management and the integrity of underground piping and tanks. Additional roadmaps will be developed as conditions warrant.

Through separately funded projects, participants can gain access to a wide range of engineering support programs, user groups, and additional training tools. The cable program, for example, provides up-to-date information on cable aging and cable aging management practices from both a technical and regulatory perspective. User groups address underground piping, heat exchanger performance, environmental qualification, and EPRI's CHECWORKS program for flow-accelerated corrosion. The Service Water Assistance Program provides a forum for sharing information pertinent to the operation and maintenance of nuclear plant service water systems.

**Accomplishments**

The Electric Power Research Institute's (EPRI's) Plant Engineering Program produces an array of guidance documents, training tools, and assessment methodologies that support safe, reliable nuclear plant operation and reduce risks associated with extended plant operation.

- Developed aging management guidance for low-voltage (less than 1 kV) and medium-voltage (2.3 kV - 34 kV) electrical cables at nuclear plants. These guides provide recommendations for establishing effective aging management programs that include data requirements, assessment criteria, health indicators, and management actions.
- Developed a reference guide to assist project teams responsible for replacing an existing large motor with a replacement that is not identical. The guidance addresses scenarios where changes in the motor design or design basis are so significant that a plant design modification would be necessary.
Electric Power Research Institute 2012 Research Portfolio

- Issued an updated reference guide that provides reference information on many of the tasks and technologies that plant owners may find useful evaluating and addressing the integrity of buried pipe.
- Formulated a 15-step process for implementing a critical spares program at nuclear power plants based on industry responses to a benchmarking questionnaire and in-depth reviews of successful critical spares programs at two nuclear plants.
- Developed engineering training modules on instrument uncertainty determination, seismic analysis, relief and safety valves, water hammer, valve actuators, and finite element analysis. Developed engineering fundamental courses on basic atomic/nuclear physics and core protection.
- Developed guidance for establishing an effective program for managing buried piping.
- Released BPWORKS™ Version 2.0, which performs risk ranking to help plant owners prioritize the inspections of buried piping and provides a database architecture for data retention.
- Compiled interim results of slow crack growth rate testing of high-density polyethylene piping to support technical justification for use of high-density polyethylene for safety and non-safety piping systems (American Society of Mechanical Engineers [ASME] Code Case N-755).

Current Year Activities

Plant Engineering Program research and development (R&D) for 2012 will focus on cabling, obsolescence, lifecycle planning guidance, secondary plant and buried piping corrosion phenomena, and training/qualification. Specific efforts will include the following:

- Develop and assess electrical cable aging management strategies
- Continue development of long-term planning products for identifying replacement needs associated with major plant components
- Initiate project to develop advanced heat exchanger performance analysis techniques
- Continue projects to understand and deal with electrical relay aging issues, both protective and control relays
- Conduct high-density polyethylene materials (HDPE) research supporting efforts to develop a regulator-accepted code case permitting the use of HDPE in ‘Code’ applications
- Support research to identify and develop technologies for interrogating buried pipe and buried pipe coatings to discern their condition
- Support research applicable to the mitigation of buried pipe corrosion such as cathodic protection and protective coatings
- Develop reference materials and calculation tools pertaining to pipe and component erosion phenomena involving liquid droplet impingement, flashing, and cavitation

Estimated 2012 Program Funding

$8.0 million

Program Manager

Brozia Clark, 704-595-2684, bhclark@epri.com
## Summary of Projects

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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tr>
<td>P41.05.02.01</td>
<td>Buried Pipe Integrity (Roadmap) (QA)</td>
<td></td>
</tr>
<tr>
<td>P41.05.02.02</td>
<td>Cable Aging Management (Roadmap) (QA)</td>
<td></td>
</tr>
<tr>
<td>P41.05.02.03</td>
<td>Procurement and Quality Issues (base)</td>
<td>Provides a utility forum for sharing procurement-related concerns and experience. Conducts research on actions to enhance vendor quality, develop common specifications, establish vendor surveillance, and detect counterfeit items. Supports an industry-wide approach to prioritization and management of obsolete items.</td>
</tr>
<tr>
<td>P41.05.02.04</td>
<td>Workforce Skills, Knowledge &amp; Assessment (base)</td>
<td>Develop training tools for engineers that can be delivered via computer-based training methodologies. Develop a methodology to validate knowledge and skills competencies and record successful completion in an industry database.</td>
</tr>
<tr>
<td>P41.05.02.05k</td>
<td>Standardized Task Evaluations for Portable Qualifications (supplemental)</td>
<td>Standardized task evaluations can help reduce or eliminate industry's duplication of effort in assessing an individual's competency and subsequent tracking of their status, which is an important element in the industry's portable qualification efforts. This program also provides guidelines for administering practical qualifications.</td>
</tr>
<tr>
<td>P41.05.02.06a</td>
<td>Cable Program (supplemental)</td>
<td>The Cable Program provides the nuclear industry with up-to-date information on cable aging and cable aging management practices from both a technical and regulatory perspective.</td>
</tr>
<tr>
<td>P41.05.02.06b</td>
<td>MV Cable Qualification (supplemental) (New)(QA)</td>
<td>The effort will establish a qualified life for the submergence of medium voltage cable starting with Kerite HTK insulation. Okonite Okoguard pink EPR insulation will be added to the program at a later date.</td>
</tr>
<tr>
<td>P41.05.02.06d</td>
<td>Heat Exchanger Performance Users Group (supplemental)</td>
<td>The Heat Exchanger Performance Users Group offers a forum for industry personnel to improve the reliability, availability, and operational capability of heat exchangers through user group meetings and reports.</td>
</tr>
<tr>
<td>P41.05.02.06h-</td>
<td>Seismic Qualification Reporting and Testing Standardization (supplemental) (QA)</td>
<td>The Seismic Qualification and Reporting and Testing Standardization (SQRUTS) program addresses nuclear plant replacement part obsolescence and attendant seismic qualification issues. Nuclear power plant members share equipment seismic testing costs and test results. A &quot;library-only&quot; membership option provides access to past completed component test reports, but without participation in the active testing program.</td>
</tr>
<tr>
<td>P41.05.02.07a</td>
<td>Buried Pipe Integrity Group (supplemental)</td>
<td>The Buried Pipe Integrity Group (BPIG) provides a forum for exchanging plant experience and supporting the implementation of advanced buried pipe assessment and mitigation technologies.</td>
</tr>
<tr>
<td>Project Number</td>
<td>Project Title</td>
<td>Description</td>
</tr>
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</tr>
<tr>
<td>P41.05.02.08a</td>
<td>CHECWORKS User Group - CHUG (supplemental)</td>
<td>The CHECWORKS User Group (CHUG) applies experience from about 260 nuclear plants worldwide to address existing and emerging issues related to flow-accelerated corrosion. CHUG provides training to new and reassigned personnel, maintains and provides updates to the CHECWORKS software, operates a dedicated website, and sponsors related research as requested by members.</td>
</tr>
<tr>
<td>P41.05.02.09c</td>
<td>Service Water Assistance Program (supplemental)</td>
<td>This project provides several forums for acquiring or sharing information pertinent to the successful operation and maintenance of nuclear plant service water systems.</td>
</tr>
<tr>
<td>P41.05.02.10c</td>
<td>PSE Equipment Performance, Monitoring and Degradation (base) (QA)</td>
<td>This project develops guidance on resolution of generic and specific aging issues, including identification, evaluation, and resolution of equipment and system aging issues. Both theoretical and practical guidance is developed including aging models, data, and acceptance criteria for components and cables; field guides for walk-downs and inspections; and development of condition monitoring techniques.</td>
</tr>
<tr>
<td>P41.05.02.11</td>
<td>Balance-of-Plant Corrosion (base) (QA)</td>
<td>Through guidance for effective buried pipe programs, risk-ranking software, and industry dialogue including interactive web, industry conferences, and other communication, this project develops tools for organizing and prioritizing nuclear power plant approaches to code acceptance of degraded piping. Through guidance for effective flow-accelerated corrosion programs, comprehensive software, and member dialogue including interactive web, industry conferences, and other communication, this project helps nuclear power plants to maintain strong stewardship over generation assets.</td>
</tr>
<tr>
<td>P41.05.02.12c</td>
<td>Engineering Technical Training Modules (supplemental)</td>
<td>Engineering computer-based training modules help meet increasing industry needs for position-specific and continuing training as new personnel are brought on board and as seasoned personnel take on new assignments. Existing training modules are being converted to computer-based training format and made available to supplemental program participants.</td>
</tr>
</tbody>
</table>

**Buried Pipe Integrity (Roadmap) (QA)**

**Key Research Question**

Many of the world's nuclear power plants have been operating for about 40 years. As such, aging mechanisms have had sufficient time to potentially challenge the structural and leakage integrity of some components such as buried piping and tanks.

Leakage from plant components has the potential to contaminate groundwater. For example, about one-third of U.S. plants have leaked some amount of liquids into the soils surrounding piping, tanks, and pipe vaults. Although these leaks and spills have not posed a hazard to human health, they have impacted public confidence. The lack of effective tools to monitor and control degradation mechanisms could degrade public and regulatory confidence and increase the likelihood of regulatory action.
Approach

Research activities are coordinated across EPRI’s Plant Engineering and NDE Programs.

The Plant Engineering Program will provide buried pipe program owner guidance documents, reference materials, and upgraded risk ranking software (BPWorks™), and also will support the development of various American Society of Mechanical Engineers (ASME) Code Cases for repair/replacement activities. Training courses will be offered for newly assigned Buried Pipe Program owners to help ensure buried pipe management guidance is appropriately deployed in the field. Reference materials on cathodic protection will be developed to address buried pipe coatings needs. Through the Buried Pipe Integrity Group, EPRI will provide a forum for information exchange among nuclear plant personnel, vendors, and other stakeholders to identify and transfer best practices for buried pipe inspection and assessment.

The NDE Program will focus on the identification and assessment of existing robotic and inspection technologies, as well as the development of new robotic inspection technologies using remote field detection technology. Efforts will continue to identify, demonstrate, evaluate, and qualify inspection technologies suitable for buried pipe applications, with special emphasis on guided wave ultrasonic technologies. Further development of guided wave will focus on modeling of defects using actual buried pipe mockup and plant removed specimens.

Impact

**Equipment Reliability and Public Confidence:** When contaminated effluent leakage events have been reported, some plants have been challenged with public confidence concerns and equipment reliability impacts.

**Regulatory:** The U.S. Nuclear Regulatory Commission issued a “Groundwater Task Force Final Report” in June 2010 which indicates that it is considering regulatory actions for leakage of licensed materials at U. S. nuclear facilities. Non-U.S. regulatory bodies are monitoring U.S. industry and regulatory activities on buried pipe and groundwater protection. The NRC has stated that non-U.S. regulators are recommending that their licensees establish actions to monitor integrity of their buried piping and other structures, systems, and components.

**Maintenance costs:** Significant portions of a nuclear plant’s buried infrastructure (piping systems) were designed and installed without regard for eventual inspection and repair needs. As a result, inspection and repair of buried components are complex tasks that can complicate outage planning and execution.

**Limitations of inspection technology:** The nondestructive evaluation (NDE) technologies that can be applied to inspecting buried piping are limited. Technologies available to the oil and gas industries are typically not immediately transferrable to a nuclear plant’s inspection needs.

**Limitations on the availability of Codes and Standards:** Codes and standards applicable for the design of buried pipe and for the “fitness for service” of buried pipe do not exist. Work is needed to support ASME development of appropriate Code Cases.

**Industry commitments:** In the United States, the nuclear industry’s chief nuclear officers have committed to two initiatives to address groundwater protection and buried piping. The 2007 initiative on groundwater protection and buried piping is aimed at preventing radioactive materials from migrating off-site. The 2009 initiative on buried piping integrity is aimed at preventing radiological and non-radiological leakage from buried piping. In August 2010, the scope was expanded to include all underground, normally inaccessible piping and underground tanks.

**How to Apply Results**

EPRI buried pipe research will result in the availability of technologies for inspection, analysis, repair, and mitigation of ongoing corrosion in buried infrastructure. This includes the following:
• Development and delivery of appropriate reference documents and training to support broad knowledge awareness around buried piping
• Development and transfer of new buried pipe inspection technologies, such as remote field NDE inspection robotics
• Identification and evaluation of existing technologies that may be directly applied or easily adapted for nuclear plant buried piping inspection
• Improved understanding regarding the usefulness of guided wave acoustic NDE technologies for buried piping screening
• Availability of repair and replacement alternatives for buried pipe applications, including high-density polyethylene (HDPE)
• Enhanced buried pipe risk-ranking technologies through updates to existing software

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Cable Aging Management (Roadmap) (QA)

Key Research Question
Concerns exist that nuclear plant safety and reliability are being adversely impacted by premature electrical cable aging-related failures resulting from exposure to localized adverse environments and service conditions. As a result, plant owners and regulators are requiring the implementation of electrical cable aging management programs and processes. Improvements to cable aging management processes, condition monitoring techniques, acceptance criteria, and aging models are necessary to support resolution of cable aging concerns. Without such improvements, cable aging management programs may have limited effectiveness.

Approach
Ease of Cable Aging Management Activities
Building on the two aging management program implementation guides already published for medium-voltage and low-voltage cable, a third guide will be issued for instrumentation and control cable. Implementation support will be provided under a 2011 to 2012 project to resolve issues that arise. In addition, a matrix linking failure mechanisms to the applicable test by insulation type will be developed in 2011 to support cable condition monitoring and troubleshooting needs.

Medium voltage separable connectors will be qualified for safety-related use during 2011 and 2012 to allow cables to be easily disconnected from their loads for testing.

Advanced Test Practices and Aging Models
Through a pilot project started in 2010, EPRI will produce age-accelerated medium-voltage cable specimens. These specimens will permit accelerated testing and forensics, accelerated development of aging models, and development of improved condition monitoring techniques.

For cable types from plants in service in the 1970s, forensic evaluation of failed cables will continue for 2 years. Results will provide insights into correspondence of condition monitoring to cable breakdown strength.

In 2011 and 2012, medium voltage test results will be gathered and assessed to develop improved acceptance criteria. Failure data also will be formally gathered and assessed.

To support the development of advanced testing practices/technologies, EPRI’s Nuclear Sector will coordinate activities and research with the Power Delivery and Utilization Sector.
**Submerged Medium Voltage Cable Qualification**

EPRI is initiating a submergence qualification project based on IEEE Std 323-1974 qualification methodology to provide a basis for allowing medium-voltage cables to be submerged. The qualification activities will be applied to modern cable types and those known to never have failed in submerged conditions. Manufacturer- and insulation-specific qualifications will be performed; generic insulation type qualification is not possible. Because certain cable types, such as most black ethylene propylene rubber (EPR) and butyl rubber, have experienced water related degradation at about 30 years, submergence qualification will not be attempted.

**Susceptibility of Low-Voltage Cable to Wet Aging**

Little information is available on longevity of low-voltage cable under wet and submerged conditions. In 2011, research will be performed that gathers existing information on submergence of low-voltage cable degradation and its effects on longevity.

**Impact**

**Safety:** A nuclear plant’s safety-related electrical cable infrastructure must be inherently reliable and maintained as such. Cable failures have challenged safety-related system readiness.

**Equipment Reliability:** Medium-voltage off-site feed cable and safety-related motor feed cable failures have caused outages of 2 to 3 weeks in duration. Medium-voltage cable replacement is costly and generally difficult.

**Regulatory:** Regulatory confidence has been eroded. The U.S. Nuclear Regulatory Commission (NRC) is requiring that cable condition monitoring be put in place. Non-U.S. regulators are following the NRC lead regarding aging cable systems. While some differences in cable materials and installation practices exist from country to country, deterioration of low- and medium-voltage cables is a concern to the world nuclear community.

**Limitations of inspection technology:** The design of nuclear plant cables limits the types of tests that may be used. While standardized, the tests provide limited information on long-term function of the cable and cannot estimate remaining life. Condition monitoring acceptance criteria is preliminary in nature and needs further improvement to assure failures are avoided and good cables are not replaced.

Limitations of applicable standards: The Institute of Electrical and Electronics Engineers (IEEE), the Insulated Cable Engineers Association (ICEA), and the Association of Edison Illuminating Companies (AEIC) have established cable testing and manufacturing standards, but these standards provide little information on aging management programs.

**How to Apply Results**

This research effort will result in knowledge and methodologies to effectively implement cable aging management programs. Specifically, the following will be provided:

- Aging management program implementation guidance for instrumentation and control cables. Medium- and low-voltage cable aging management program guidance has previously been provided.
- Recommended testing methodologies applicable to specific cable types and vintages.
- Advanced testing and predictive capabilities.
- Additional understanding of electrical cable failure modes allowing improved testing methodology and acceptance criteria to be developed.
- Useful research results/products aiding in the implementation of aging management programs. This includes test applicability matrices, qualification of separable connectors, and ongoing EPRI technical support.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.
Procurement and Quality Issues (base) (065801)

Key Research Question

Supporting procurement of spare and replacement items required for operation and maintenance involves a number of specialized engineering processes such as safety classification, commercial grade dedication, and equivalency evaluation. Existing processes must be adjusted occasionally to address considerations such as critical spares, obsolescence, and emerging regulatory expectations.

Issues directly related to the quality of procured items continue to impact plant reliability. Poor product quality may be due to deficiencies originating in both buyer and supplier organizations. Identified contributors to poor quality include loss of supplier expertise and understanding, inadequate specification development and communication of technical requirements, increasing reliance on foreign materials and manufacturers, and the vintage of operating plant equipment and its design. Additional focus and guidance are needed to better understand and address the root causes of poor product quality. In particular, repair and replacement of large equipment have been problematic. Collection and analysis of data related to failure of procured items is needed to more effectively identify and address problematic trends.

Approach

This project consists of three principal elements:

1. Continuing support of utility forums including the Joint Utility Task Group (JUTG) and the Nuclear Supply Chain Strategic Leadership (NSCSL) to identify and address technical procurement and supply chain concerns. Continued coordination with the Nuclear Procurement Issues Committee (NUPIC), Nuclear Utility Obsolescence Group (NUOG), and ASME NQA-1 Committees

2. Development of new guidance and information to address technical supply chain issues, such as mitigating the use of counterfeit and fraudulent items, adapting commercial grade dedication methodology for use in accepting commercial-grade software, defining and implementing processes to improve product quality and address obsolescence

3. Development and maintenance of technical procurement training courses and products

Impact

- Stay current with regulatory expectations and emerging regulatory positions and guidance
- Maintain current procurement engineering processes such as functional safety classification, commercial-grade item dedication, reverse engineering, and equivalency evaluation that permit spare and replacement item needs to be met in a timely and cost-effective manner
- Development of standard approaches to address emerging issues such as supplier foreign material exclusion practices
- Improve equipment reliability and performance through better understanding and improvement of product quality issues
- Enable implementation of programmatic solutions to prevent the use of counterfeit and fraudulent items, improve the quality of procured items, address obsolescence, and improve availability of critical spares
- Effective training in areas related to procurement such as warehousing, receipt inspection, procurement engineering, audit technical specialists, ASME procurement, and foreign material exclusion

How to Apply Results

Members use project information to enhance procurement engineering programs, improve communication with suppliers, improve specification development, identify and prioritize obsolescence issues, identify and address critical spares needs, and improve product quality.
**Workforce Skills, Knowledge & Assessment (base) (065802)**

**Key Research Question**

Turnover of nuclear plant technical staff will be significant in the next 5 to 10 years. During the same timeframe, nuclear utilities will be training personnel to support construction and operation of new nuclear plants. Pressures to reduce operations and maintenance costs often result in impacts to training budgets. Also, fewer and fewer skilled supplemental workers are available for working power plant outages. Often, as the supplemental outage workers travel from plant to plant, they receive the same training and examinations at each plant. In this environment, nuclear plants need cost-effective methods to develop and deliver high-quality, effective training and be able to quickly validate the skills competencies of the supplemental workers.

**Approach**

Computer-based training technology can improve the effectiveness of engineering training and reduce the costs associated with providing this training. Plant Support Engineering (PSE) is engaged in developing computer-based training for nine engineering fundamentals topics included in the Institute of Nuclear Power Operations (INPO) guidelines for orientation of new engineers. PSE also is transferring materials related to its Standardized Task Evaluations onto NANTeL; these knowledge examinations and skills proficiency demonstration examinations can be administered to supplemental workers to verify skills competencies. Any power plant with access to NANTeL can download the examination materials, administer the examinations, and record an individual's successful completion within the NANTeL system. This will serve as a basis for accepting prior qualification testing in lieu of re-administering knowledge and skills training and examination.

**Impact**

Stations are using the engineering computer-based training (CBT) modules in lieu of classroom-conducted training sessions to provide orientation training to new engineers. This results in fewer disruptions for engineering organizations and also frees up instructor time associated with class lecture and examination preparations.

By verifying prior completion of knowledge and skills qualification-related examinations using the NANTeL or EPRI databases, utilities are experiencing cost savings associated with streamlining the in-processing, training, and qualification of supplemental personnel.

**How to Apply Results**

The content of the engineering training modules will be available both from EPRI as well as an industry web-based training delivery system (INPO’s NANTeL system) where students can complete the CBT and take the course examination. For qualification of outage supplemental personnel, knowledge examinations and skills proficiency demonstration examinations can be accessed via NANTeL, administered, and results recorded within the NANTeL database. Once the record of successful completion is recorded in the database, the record of successful completion can be used by other utilities as a basis for exempting their examination requirements when the supplemental worker arrives at their station for outage work.

**Standardized Task Evaluations for Portable Qualifications (supplemental) (005354)**

**Key Research Question**

Utility and supplemental personnel are critical to a plant's ability to conduct quick-turnaround refueling outages. Recent trends show a disproportionate occurrence of events associated with supplemental personnel. EPRI's Standardized Task Evaluation program (formerly called the Task Proficiency Evaluation program) provides a proven knowledge and skills evaluation process to efficiently evaluate the capabilities of entry-level, incumbent, and contractor personnel. The program is working within the framework of the Nuclear Energy Institute's Workforce Issues initiative and with the Institute of Nuclear Power Operations’ National Academy for Nuclear Training e-Learning (NANTeL) portable qualification project to establish an infrastructure that ensures the competency of the industry's craft and technician workforce. The standardized task evaluations are not
restricted to U.S. applications; utilities in France, South Africa, and Canada have expressed interest in adapting such evaluations to their own countries.

Additionally, the need to implement an industry consensus for standards for administering practical qualifications has been identified.

**Approach**

Standardized task evaluations are used to ensure that the workforce is competent to reliably perform the many tasks associated with operating and maintaining industry facilities. Program participants continue to collaboratively develop evaluation tests that support high-priority industry needs. More than 60 evaluations have been developed within the STE Program and are available on www.epri.com. These evaluations, which cover tasks performed by utility and supplemental workforce during outage work, include a task analysis and objectives, written test items, and performance (practical) evaluations. Additionally, the results from these evaluations are documented into a national registry of personnel who have demonstrated competency in specific task areas.

**Impact**

Participating organizations can use the STE evaluations to assess the competency of their workforce, thus eliminating unnecessary training or retraining. Further, because the modules were developed according to EPRI's Administration Protocol for Portable Practicals (AP3), they reflect industry consensus standards for administering practical evaluations.

**How to Apply Results**

Training and maintenance managers can directly access the STE modules through multiple channels:

- Identifying and downloading evaluations through www.epri.com for use by participating organizations with specific task needs
- Accessing evaluations available on INPO's NANTeL System (http://www.nantel.org) for use by participating organizations for on-line testing and for reporting results
- Accessing the registry of qualified personnel on www.epri.com
- EPRI Report 1021072, *Administration Protocol for Portable Practicals (AP3) in Standardized Task Evaluations*

**Cable Program (supplemental) (005614)**

**Key Research Question**

The aging of medium- (<4160 V+) and low-voltage (<1000 V) cable systems has raised regulator interest in the ability of these systems to perform their safety and support functions. This program supports the industry by disseminating information on how cable systems age and the best means for detecting and mitigating aging effects.

**Approach**

This project offers a forum to the industry to address issues related to cable-system-aging management through the Cable User Group, which transfers cable research results to members in practical terms and supports the identification, discussion, and resolution of cable system issues. Feedback from the Cable User Group meetings is used to guide cable research on aging model and condition monitoring development. In 2012, the focus of meetings will continue to be on resolution of hurdles to the implementation of cable aging management.

As funding permits, technical reports will be generated on cable-aging-related topics of interest to program members. In 2012, the Cable Program will develop computer based training packages that describe cable aging management methods and technology. These will only be available to Cable Program members.
In addition, the Program provides access to Electric Power Research Institute (EPRI) personnel conversant in cable-aging management issues allowing utility personnel to discuss plant problems and their resolution.

**Impact**

Benefits accrue through direct access to experts in cable-aging management and cable condition monitoring. Participants also help shape the path of cable-aging management research to ensure its pertinence to nuclear plant applications.

**How to Apply Results**

Cable User Group attendees have direct access to EPRI and industry experts in condition monitoring, cable manufacture and installation, and the discussion of the latest industry issues and practices. Research results are provided in EPRI research reports and meeting minutes from the Cable User Group meetings.

**MV Cable Qualification (supplemental) (QA)**

**Key Research Question**

Submergence of medium-voltage (4160 V+) cables has raised regulatory concern regarding the ability of these cables to perform their safety and support functions. EPRI is developing an environmental qualification program that could allow continued use of cables subjected to long-term submergence.

Cable failures in non-safety applications have caused plant shutdowns and trips, primarily traced to pre-1975 cables. While later-generation Kerite brown ethylene propylene rubber (EPR) cables and Okonite pink EPR cables have not experienced submergence-related failures, the Nuclear Regulatory Commission (NRC) has determined that submergence was not part of the original design. Accordingly, the NRC is requesting that nuclear plants licensees drain—and keep drained—all manholes, vaults, and ducts. For physical and economic reasons, not all plants can do so. Cable relocation into new ducts could cost $5 million or more for design and installation. The alternative is to develop an environmental qualification for energized cables that have been submerged either continuously or for long durations.

**Approach**

This project will develop an environmental qualification for submergence of non-shielded brown Kerite medium-voltage cable. A separate project will develop a similar qualification program for Okonite non-shielded pink EPR cable.

The qualification will be based on two methods described in IEEE Standard 323-1974: Operating Experience (Section 5.2) and Ongoing Qualification (Section 5.5). The methodologies defined in these sections are endorsed by the NRC in Regulatory Guide 1.89, Revision 1 without exception.

Environmental qualification of Kerite cable for harsh environment applications exists under the manufacturers’ environmental qualification. That qualification, however, does not cover long-term, normal condition submergence of energized cables. The proposed project, therefore, will develop a qualification for segments of energized cables subject to long-term submergence.

Although the submerged portions of cables do not experience a change in environment as a result of design basis accidents, it is possible that they would be de-energized by a loss-of-offsite power and re-energization concurrent with a design basis accident. The project will simulate re-energization and the associated switching surges to evaluate such scenarios.

The “operating experience” portion of the qualification will be based on assessment and testing of a 30-year-old cable removed from an operating power plant that has been submerged for a period of time. Once the condition of this cable is fully characterized, a qualification by “operating experience” will be established for 30 years. The tests will include breakdown testing to determine the ratio of the breakdown voltage to the operating voltage.
To establish “ongoing qualification,” the breakdown fault will be removed from the cable and 30-ft. specimens will be prepared and subjected to long-term energized accelerated aging.

The ongoing qualification and the operating experience qualification will determine the qualified life of the cable, which will be incremented for each year of satisfactory function and periodic test results under accelerated submerged conditions. For example, after the first year of laboratory aging, the qualification would result in a 32- to 40-year qualified life. After the second year, the qualified life would increase to 34 to 50 years, and so on.

Impact

Plants with non-shielded brown Kerite medium-voltage cable will gain access to a qualification demonstrating that the cables can withstand long-term submergence while subjected to operating voltage. Conversely, if the qualification program identifies end-of-life at some point during testing, nuclear plant owners will know when to plan for cable replacement.

Participation would enable nuclear plant owners to
- save millions of dollars in design and implementation costs for cable relocation if cable ducts and manholes cannot be drained,
- determine a qualified life for cables that can’t be tested using available condition monitoring techniques, and
- assess whether periodic or continuous submergence causes unacceptable shortening of cable life.

How to Apply Results

The results can be used to establish a period for which the cable can remain submerged without undue degradation. This will be the base report that will be followed by periodic reports on the accelerated, laboratory-based, submergence qualification that will extend the base period.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td>Operating Experience Based Submergence Environmental Qualification of Kerite HTK Insulated Cable: The results of the testing and assessment of a Kerite HTK insulated, non-shielded cable will be provided that will form the basis of the submergence environmental qualification for the duration of the installed-operating period of the cable.</td>
<td>12/21/12</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>

Heat Exchanger Performance Users Group (supplemental) (045060)

Key Research Question

This project offers a forum for industry personnel to improve the reliability, availability, and operational capability of heat exchangers (with the exception of steam generators). The project allows participants to share operational experiences and to resolve technical issues associated with heat exchangers.

Approach

- Information sharing with Heat Exchanger Performance User Group (HXPUG) members
- Technical investigations and research on issues related to heat exchangers that are a high-priority to the group
- Annual meetings and quarterly webcasts to share information and keep membership engaged
- Availability of information sharing through website and surveys to benchmark other utilities in the operation and maintenance of heat exchangers
- Collaboration on common industry problems and solutions as they relate to heat exchanger testing and performance

**Impact**

The project offers an estimated cost savings of $25,000 to $100,000 annually per plant using the information available through the HXPUG group facilitating the following:

- Improved testing methods through collaboration with industry personnel and use of EPRI guidelines
- Avoided costs through the reduction of unnecessary heat exchanger testing
- Improved plant performance through improved thermal performance of the feedwater heater, moisture separator reheater, and condenser
- Improved efficiency in heat exchanger program implantation and maintenance practices from guidance issued by the group
- Collaboration on common industry problems and solutions as they relate to heat exchanger testing and performance

**How to Apply Results**

Participating members in the Heat Exchanger Performance User Group can implement the lessons learned and information generated in this group. Examples include improved heat exchanger performance testing methods, guidance for heat exchanger program owners and system owners for maintaining exchanger reliability, and avoiding issues experienced at other plants.

**Seismic Qualification Reporting and Testing Standardization (supplemental) (QA) (004414)**

**Key Research Question**

Component obsolescence remains an industry challenge in the maintenance of nuclear plants, and with the prospect of even longer-term operation, replacement parts for existing facilities will continue to drive costs higher. Component qualification to individual utility design specifications constitutes a significant cost in the dedication of replacement parts. The Seismic Qualification and Reporting and Testing Standardization (SQRUTS) program, conceived in the early 1990s to address nuclear plant component obsolescence issues, applies the economies of scale of member utility owners and operators to share component seismic testing specifications, costs, and test results.

**Approach**

Seismic testing conducted through the SQRUTS program involves component testing at a service vendor facility nominally 8 weeks per year. Utility participation is critical in developing generic test specifications and component test procedures, witnessing test performance and approving test reports, and participating in user meetings.

Members also have access to a seismic test report database comprised of SQRUTS-performed test results and individual member test reports (should they choose to enter them). EPRI provides project management for the program, including contracting test services, budget forecast, tracking and reporting, database management, test report distribution, user communication, initiative coordination, and member meetings.

EPRI provides an option for membership in the Library only; this provides access to past completed component test reports. However, participation in the active testing program is not permitted if only this option is selected.
Impact
The program enables members to reduce component seismic testing costs through economies of scale and the shared database that members can use for component evaluations.

How to Apply Results
Results are generally implemented immediately by participants. Testing is driven by the needs of the members, and the database is accessed on member demand. Design engineers, seismic subject matter experts, and procurement engineers are typical customers of the SQURTS program.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Future Year Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQURTS Database Enhancements: SQURTS Database Enhancements will be issued as a new release of the current v2.0. It will be QA. Enhancements include further functionality based upon user feedback and streamlining of new data input administrative requirements.</td>
<td>06/15/12</td>
<td>Technical Resource</td>
</tr>
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</table>

Buried Pipe Integrity Group (supplemental) (068003)

Key Research Question
Buried piping has become a more visible issue with regulatory emphasis on material aging issues and plant life extension requirements. Due to aging of external protective coatings as well as a multitude of internal and external piping corrosion mechanisms, each nuclear plant’s buried pipe infrastructure is susceptible to leaks and failures. Leaks can be difficult to locate. Also, some may contribute to contamination of groundwater. All buried pipe leaks can be expensive to repair due to accessibility issues. Some leaks may require a plant shutdown for repair. A broad-based and comprehensive program is needed to support plant efforts to reduce the probability and consequences of failure to an acceptable level.

Approach
The Buried Pipe Integrity Group (BPIG) provides a forum for exchanging plant experience and provides counsel and recommendations as to the implementation of advanced buried pipe assessment and corrosion mitigation technology.

Impact
- Assess the health of existing piping and determine remaining service life.
- Develop methods to repair buried piping in situ.
- Select and qualify alternate materials and service environments (for example, high-density polyethylene, water treatment, and cathodic protection).
- Provides a forum for the buried pipe services industry to interface with buried pipe engineers from participating utilities.
- All United States Nuclear utilities and several international participants were members of the BPIG in 2011.
How to Apply Results

Members will apply the results of this project in developing effective buried pipe integrity programs and in assessing and maintaining existing buried piping systems.

2012 Products

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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</thead>
<tbody>
<tr>
<td>Buried Pipe Integrity Group Meeting</td>
<td>02/29/12</td>
<td>Workshop, Training, or Conference</td>
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<tr>
<td>Buried Pipe Integrity Group Meeting</td>
<td>07/31/12</td>
<td>Workshop, Training, or Conference</td>
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CHECWORKS User Group - CHUG (supplemental) (052460)

Key Research Question

Although industry efforts have been effective in reducing the number of piping and equipment failures caused by flow-accelerated corrosion (FAC), piping and components remain susceptible to degradation as plants age. Refined guidance on where to inspect, chemistry improvements to reduce damage rates, and material upgrades for replaced components is needed to offset challenges posed by economic considerations, short outages, and personnel turnover.

Mechanical pipe degradation caused by cavitation, liquid droplet impingement, flashing, and solid particle erosion can affect personnel safety and cause power losses. Damage caused by these mechanisms is nonlinear with time and often results from off-normal operations.

Approach

The CHECWORKS User Group (CHUG) applies experience from approximately 260 nuclear plants worldwide to address existing and emerging issues related to flow-accelerated corrosion. CHUG provides training to new and reassigned personnel, maintains and provides updates to the CHECWORKS software, operates a dedicated website, and sponsors related research as requested by members. This includes research and guidance to address detection of erosion damage in high-energy piping systems.

Impact

- Minimize risk to personnel by reducing the probability of large-bore pipe ruptures
- Reduce forced power reductions through FAC mitigation
- Reduce the number of piping inspections through improved guidance, predictive software, and piping replacements (some plants have observed a 25% reduction over a 6-year period with average estimated savings of $2,150,000 per outage per plant)
- Develop practical tools to optimize FAC programs, such as NDE data evaluation techniques and application guidance for material alloy analyzers that can be used to reduce the number of inspections
- Identify new FAC vulnerabilities before leaks occur
- Train new and reassigned plant engineers on FAC identification, monitoring, and mitigation
- Facilitate interaction with industry peers and ease access to reports and other information
How to Apply Results

Members use CHECWORKS to predict plant degradation and reduce unneeded piping inspections. Technical guidance related to pipe alloy analyzers, erosion, and low-temperature FAC provide members with information to optimize inspection locations. Members can access training for new and reassigned personnel and can use the CHUG website to facilitate communications between FAC personnel at member plants.

2012 Products

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<thead>
<tr>
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<tbody>
<tr>
<td>Demonstration of New Multiple Inspection Data Evaluation Methods: The evaluation of inspection data is an important part of a FAC program. Recently, EPRI has developed several methods that appear to be improvements on the current ways of evaluating data from two or more inspections. It is planned that some of these methods will be included in CHECWORKS™ Version 4.0 - next major release. This project will compare the predictions of the currently used methodologies with the Least Squares Slope method and the Slope of the Minima method using selected lines from one or more plant databases.</td>
<td>01/01/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td>Update on FAC Weld Attack: This project should provide the knowledge and expertise to help protect against failures caused by preferential weld attack and help to design inspection programs to protect against this form of degradation. It also will increase the store of knowledge related to weld attack and increase the visibility of a BOP-wide vulnerability to leaks and ruptures.</td>
<td>01/01/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Review of the CHECWORKS/SFA Line Correction Factor Methodology : The determination of the Line Correction Factor (LCF) is a key element in performing the CHECWORKS™ Pass 2 predictions. This methodology used has been unchanged since the late 1980s and has never been challenged by other possible methods. This project will provide a detailed description of the current methodology used to calculate the LCF, define other possible methodologies for making this calculation, compare the results of predictions using the current method with the newly defined methods for one or more plant databases, and recommend the methodology that will be used in Version 4.0.</td>
<td>01/01/12</td>
<td>Technical Resource</td>
</tr>
<tr>
<td>2011 State of the Fleet FAC Program Assessments: This project provides insight from a variety of plants as to the status and overall effectiveness of FAC program implementation and the associated challenges by performing an overall program review, analogous to a detailed self-assessment, at five sites in 2011 and 2012. The consolidated report would assist FAC engineers in the development of long-range plans, identifying industry “best practices”, implementation of program process improvements, and identification of declining program trends.</td>
<td>03/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td>Revision of CHECWORKS/SFA to version 4.0 : The revision of CHECWORKS/SFA to version 4.0 will include the expanded use of the component connectivity feature, the incorporation of new data evaluation methods, additional custom report options, and the new erosion analysis module.</td>
<td>12/31/12</td>
<td>Software</td>
</tr>
<tr>
<td>Study of the Material Form Effects on FAC: Understanding the role of material form will help better focus FAC inspection programs. It also would open the possibility of developing methods to reduce the susceptibility of carbon steel components to FAC.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
</tbody>
</table>
Service Water Assistance Program (supplemental) (070808)

Key Research Question
Nuclear plant service water systems are complex systems that can occasionally provide engineers with day-to-day challenges. Service water system performance can be improved by providing engineers with access to a collaborative environment where thoughts, ideas, and solutions can be readily available and shared.

Approach
Project participants gain access to the Service Water Assistance Program (SWAP) web page, which includes the SWAP technical library, SWAP surveys, a listing of SWAP coordinators, and easy access to SWAP products. Members also can query the nuclear industry on service water problems through industry SWAP surveys. Members also can obtain personal assistance from EPRI personnel via phone or email. EPRI also sponsors an annual meeting of SWAP coordinators for sharing operating experience and discussing solutions to field problems. Training courses for service water engineers are available on heat exchangers, piping, and corrosion mechanisms.

Impact
The SWAP technical library, which contains more than 2350 documents on 300 subjects, can be searched by subject, author, and/or date. Many of the titles are available for download as PDF files. The annual meeting and access to EPRI experts provide opportunities to discuss plant issues and identify potential solutions.

How to Apply Results
The SWAP coordinators serve as the point of contact between the EPRI SWAP program and the plant. Active participation facilitates technology transfer and maximizes benefits received. A SWAP Coordinator's Manual helps guide access to SWAP resources and services.

2012 Products

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<tbody>
<tr>
<td>Annual Service Water Assistance Program Meeting</td>
<td>08/31/12</td>
<td>Workshop, Training, or Conference</td>
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</table>

Future Year Products

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<tbody>
<tr>
<td>Annual Service Water Assistance Program Meeting</td>
<td>08/30/13</td>
<td>Workshop, Training, or Conference</td>
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PSE Equipment Performance, Monitoring and Degradation (base) (QA) (065799)

Key Research Question
Material degradation reduces the inherent design margins in plant equipment. Unanticipated or unaccounted for degradation has led to equipment failures, affecting critical plant functions and representing a major threat to achieving equipment reliability goals. In many cases, aging models and condition monitoring techniques do not exist, and where they do they exist, readily understandable acceptance criteria may not exist. When
replacements are necessary, superior materials or components may not have been identified or recognized as acceptable for nuclear service.

**Approach**

This project develops guidance on resolution of generic and specific aging issues, including identification, evaluation, and resolution of equipment and system aging issues. Both theoretical and practical guidance is developed including aging models, data, and acceptance criteria for components and cables; field guides for walk-downs and inspections; and development of condition monitoring techniques. New materials such as plastic piping are evaluated for use in nuclear applications. Information is disseminated through industry meetings such as the Equipment Reliability Forum.

**Impact**

- Avoid in-service failures and potential plant outages through improved detection of component degradation
- Predict remaining life and evaluate the seriousness of equipment degradation through access to aging data, interpretation of that data, and acceptance criteria
- Enhance ability to identify, assess, and manage aging through field guides and aging management guidance
- Assure broad distribution degradation research results and information through meetings such as the Equipment Reliability Forum
- Improve assessment techniques to identify components and materials prone to early aging

**How to Apply Results**

Because multiple tasks are performed under this project, member applications vary. Field guides and aging management guides are applied directly. In other cases, information is provided in the Equipment Reliability Forum to promote understanding and availability of research results, or incorporated into training courses.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

**Balance-of-Plant Corrosion (base) (QA) (052459)**

**Key Research Question**

Corrosion in the secondary systems of nuclear plants can result in annual costs of up to $25 million per plant. These costs are primarily associated with corrosion product transport in boiling water reactors, flow-accelerated corrosion in steam and feedwater systems of all types of nuclear plants, degradation in service water systems, and degradation in raw water heat exchangers, including the main condenser. Without intervention, these costs will increase as plants age. A specific issue impacting plants considering life extension is the health of buried piping. Inspection, repair, and replacement of these lines can be extremely expensive, particularly in buried lines that pass beneath buildings and equipment.

**Approach**

The Balance-of-Plant Corrosion (BOP) program develops the technology, tools, and software to cost-effectively address corrosion issues in the BOP portions of nuclear power plants. BOP corrosion has spearheaded the development of improved inspection technology to assess the health of secondary systems and the use of alternate materials to reduce cost and improve the service life of BOP piping and components.

**Impact**

- Data and methodology to allow use of high-density polyethylene as an option to repair or replace corroding steel pipe in Class 3 service water systems.
- Computer-based modules to train new and reassigned plant personnel on the most common forms of corrosion in the secondary systems of nuclear plants.
- Mitigation technologies to address buried pipe degradation.
- Risk-ranking software tool to prioritize buried pipe inspections. This tool calculates the probability of a leak occurring in each segment of buried piping, considers the consequences of a leak at each specific location, and derives a calculated "risk."
- Robust inspection technology and guidance to assess the health of large-diameter and intermediate-diameter buried piping. The "proof-of-concept" of a large-bore pipe inspection tool (3-foot to 12-foot diameter) was completed in 2008. An intermediate pipe diameter tool is currently in development and scheduled for "proof-of-concept" testing at a nuclear power plant during the spring 2011 outage season.
- Research to support the American Society of Mechanical Engineers (ASME) in developing "design rules" and "fitness-for-service" rules for buried pipe.

How to Apply Results

Data supporting the use of high-density polyethylene as a repair and replacement option for corroded steel service water systems has been provided to ASME and is available for members to incorporate into code cases. Computer-based training modules are available to members and can be modified for plant-specific information.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Engineering Technical Training Modules (supplemental) (005556)

Key Research Question

As new engineering personnel are brought into the workforce and as individuals are moved into different assignments, position-specific training modules can accelerate their acclimation and value to the nuclear industry. If training modules are not readily available to meet the needs in these cases, organizations typically have to develop specialized courses (not cost effective in most cases) or find course offerings available elsewhere in the industry. Unless the topic is one that is routinely offered, the availability of a course will not likely meet scheduling needs.

Approach

EPRI's computer-based training (CBT) modules can be used for position-specific and continuing training needs for selected topics. Forty-five modules were developed several years ago using PowerPoint™ slides and companion Word™ documents. This information is being used as a basis for the new modules; however, the content is being updated and photographs and graphics are being used along with interactive features to enhance the training. The CBT modules are much more in line with expectations of new engineers entering the workforce. Twenty-two modules were previously converted, and more will be converted in 2011. Modules are being selected on a priority basis to meet industry needs.

Impact

Based on today's demographics, personnel turnover in the nuclear power industry will be quite significant in the coming years. The need for this training is increasing as new personnel are hired and seasoned employees are reassigned as a result of personnel turnover. These CBTs have the following attributes:

- Can be downloaded for use when needed from http://www.epri.com
- Provide basic position-specific training for new hires and individuals reassigned to new jobs
- Can be used for continuing training

How to Apply Results

Engineering supervisors and training personnel should be aware of these modules and use them for position-specific and continuing training as appropriate.
Instrumentation and Control

Program Overview

Program Description

Instrumentation and control (I&C) systems affect all areas of plant operation and can profoundly impact plant reliability, efficiency, and operations and maintenance costs. Plants are facing changes that involve serious I&C-related challenges—equipment is getting older and cost-effective operation is more critical.

The Electric Power Research Institute's (EPRI's) Instrumentation and Control program provides the technical bases to apply advanced I&C and information technologies so that existing and new nuclear plants can tap into functionality and capabilities underutilized to date in the nuclear sector. These capabilities will enable nuclear plants to maintain safe operation while managing I&C obsolescence with higher equipment reliability and personnel productivity. EPRI research focuses on improving the reliability of existing I&C systems and components, enabling the implementation of replacement I&C systems and advancing the use of I&C to enhance plant health and productivity.

Research Value

Research results from the Instrumentation and Control Program enable nuclear plants to apply I&C systems in an effective manner that supports safe, reliable plant operation. Advanced I&C research provides the technology and knowledge base so plant owners can potentially realize direct and indirect cost savings, make technically sound system- and component-level decisions, and comply with regulatory requirements. Instrumentation and Control Program participants gain access to the following:

- Strategic roadmaps outlining research gaps confronting key issues—such as digital I&C implementation—and the collaborative actions needed to address these gaps
- Life-cycle management and maintenance guidelines for generic existing I&C systems and components
- Technical bases for the generic resolution of regulatory issues for new and operating plants, such as risk-informed defense-in-depth and diversity assessment guidance, cyber security guidance, and guidelines for electromagnetic interference testing and digital upgrades
- Technical evaluations for new technologies in nuclear applications, such as programmable controllers, “smart” sensors, and wireless communications
- Guidance in setting up automated asset- and equipment-monitoring systems that will improve overall plant reliability
- Improved decision-making tools such as control room human factors guidelines, improved information access and visualization, and visualization-enhanced approaches for tacit knowledge capture and training
- Training, operating experience, and lessons learned on I&C replacement projects that will enable plants to avoid costly mishaps and electromagnetic interference events and to implement plant strategies to cost-effectively manage I&C obsolescence

Approach

The I&C Program is designed around three main initiatives:

- Improve Reliability of Existing Systems and Components: I&C systems such as printed circuit cards must be reliable to avoid unplanned plant trips and down-powers. This project develops generic technical bases for effective maintenance and life-cycle management of I&C systems and components already installed in the plant, which will always be required to maintain and improve the reliability of the existing I&C systems and equipment. Key research products include life-cycle maintenance guidance for analog and digital circuit card systems and industry-accepted preventive maintenance guidelines for digital systems to reduce failures and inappropriate maintenance activities.
- **Enable Replacement System Implementation:** As the nuclear industry transitions from analog to digital technology, there are several I&C-related issues for which the available technical and regulatory guidance is unclear, incomplete, or evolving. Examples include failure analysis, cyber security, defense-in-depth and diversity, various design considerations for control rooms, and the impact of new technologies such as field programmable gate arrays. This project develops the technical bases to support the deployment and licensing of I&C and human system interface (HSI) replacement systems; develops guidelines for implementing new I&C, information, and HSI technologies in nuclear applications; and documents operating experience and lessons learned.

- **Use Advanced I&C to Improve Overall Plant Health and Productivity:** Existing plant I&C equipment and functionality do not accommodate up-to-date features and techniques that can reduce costs and enhance reliability and productivity. Expanded capabilities can streamline many plant tasks and procedures to reduce operations and maintenance costs while improving reliability and extending component lifetimes. This project will pursue advanced technologies such as remote monitoring, wireless communication, early prognosis, and data visualization, which could yield benefits such as calibration interval extension, on-line equipment condition assessment, self-testing and diagnostics, and improved access to plant data.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate and execute needed research among multiple entities. For the I&C Program, a roadmap has been developed to address the technical barriers that have precluded widespread digital I&C implementation. Additional roadmaps are under development for circuit card aging and obsolescence management, I&C reliability, and continuous on-line monitoring.

Through separate supplemental projects, nuclear plant owners can gain access to additional research opportunities, including implementation support for I&C maintenance and life-cycle management programs, development and demonstration of new technologies for improving I&C productivity, and forums for sharing lessons learned on reliability, digital I&C implementation, and fleet-wide monitoring.

**Accomplishments**

EPRI's Instrumentation and Control Program has provided much of the fundamental basis supporting digital implementation in the nuclear industry and in identifying and overcoming many of the barriers to implementing newer technology. These include the following:

- Developed a life-cycle management guidance document for circuit cards. The report provides guidance to increase the reliability and operating life of existing circuit cards and components, such as guidelines for the proper handling of printed circuit cards and their components.
- Assessed the benefits of I&C defense-in-depth and diversity from a risk perspective. Higher-frequency events such as turbine trip and loss-of-feedwater showed greater safety benefits than rarer accident sequences such as loss-of-coolant.
- Developing a failure analysis guideline for digital systems that can be used to inform decisions on I&C architecture and overall system reliability.
- Obtained U.S. Nuclear Regulatory Commission approvals in safety evaluation reports on various guidelines/requirements (digital platforms, commercial off-the-shelf components, electromagnetic interference testing).
- Issued technical guideline for cyber security requirements and life-cycle implementation of nuclear plant digital systems. This guideline details 138 areas of security, covering everything from passwords and wireless connections to encryption and intrusion detection. Two appendices lay out exact steps to follow to address cyber security when designing and installing a new digital I&C control system.
- Developed technical guidelines for using field programmable gate arrays (FPGAs) in nuclear safety-related applications.
- Produced a Nuclear Sensor Roadmap that describes sensor-related issues, needs, and technologies relating to aging and obsolescence, I&C retrofits, power uprates, long-term operations, and new builds. A key conclusion is that the relatively small market for nuclear-grade sensors leaves the industry vulnerable to near-term supply shortages and may lead to under-investment in emerging technologies.
• Developing implementation guidance and summary of all research to date on instrument calibration extension.
• Issued guidance for the implementation of wireless networks in nuclear power plants, with a secondary emphasis on the use of wireless sensors for asset condition monitoring. Guidance includes technical details and real-life experiences from industry and addresses concerns such as cyber security and electromagnetic and radio frequency interference.

Current Year Activities
I&C Program research and development for 2012 will focus on life-cycle management, new I&C system implementation, equipment reliability, and plant productivity. Specific efforts will include the following:
• Update failure modes and mechanisms report for printed circuit card systems
• Develop guidance on replacement of analog circuit cards with FPGA based substitute cards
• Develop guidance for maintenance of programmable digital based systems
• Update computer-based training modules on implementing digital I&C to facilitate utility application with reduced cost and greater convenience
• Develop algorithms and techniques to integrate modeling and monitoring results to provide better indication of equipment health

Estimated 2012 Program Funding
$3.3 million

Program Manager
Robert Austin, 704-595-2529, raustin@epri.com

Summary of Projects

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P41.05.03.01</td>
<td>Roadmap</td>
<td>Digital I&amp;C implementation (Existing Plants)(Roadmap) (QA)</td>
</tr>
<tr>
<td>P41.05.03.02d</td>
<td>I&amp;C Productivity Improvements (supplemental)</td>
<td>The ability to improve plant performance and reduce operations and maintenance costs over the extended life of plants is becoming increasingly difficult with current technology and workloads. The I&amp;C Productivity Improvements project will identify implementation opportunities through new technologies and new work task definitions that can cost-effectively improve performance, reduce costs, and lead to new plant capabilities.</td>
</tr>
<tr>
<td>P41.05.03.03a</td>
<td>Digital I&amp;C Implementation (supplemental)</td>
<td>The Digital I&amp;C Implementation project group coordinates at least one workshop per year to promote discussion and resolution of problematic digital I&amp;C implementation issues and development of new solutions, guidance, and training materials when needed.</td>
</tr>
<tr>
<td>P41.05.03.04</td>
<td>I&amp;C Reliability (supplemental)</td>
<td>Instrumentation and control (I&amp;C) maintenance and life-cycle management has emerged as a critical reliability issue for operating nuclear plants. The I&amp;C Reliability project provides participants with implementation support for I&amp;C maintenance and life-cycle management programs and a forum for sharing experiences and identifying research needs to address emerging problems.</td>
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</table>
Digital I&C implementation (Existing Plants)(Roadmap) (QA)

Key Research Question

Operating nuclear plants are gradually transitioning much of their aging and obsolete instrumentation and control (I&C) equipment from analog to digital technology. However, despite significant safety, reliability and performance advantages, its acceptance and use have been slow to develop in the nuclear power industry. Plants have experienced significant unanticipated costs, delays and operating events associated with digital system implementations. As a result, the risks associated with I&C upgrades are often judged to be greater than the risks of continuing to operate with obsolete analog equipment.

Approach

EPRI will develop its guidance and training modules on a topic-by-topic basis, using technical advisory groups (TAG) comprised of knowledgeable utility, INPO, NEI, and industry representatives. The TAGs will guide product development and act as reviewers and contributors to ensure that the products have appropriate scope, detail, and practical utility for their intended users. Products will be updated on an as-needed basis as new information and operating experience become available and new technical and regulatory issues come to light. When appropriate, EPRI products may be forwarded to others, for example to NRC for endorsement, to the Advisory Committee on Reactor Safeguards (ACRS) for information, to standards organizations for incorporation into their guidance, to NEI for use in supporting regulatory positions, and to INPO for training or further distribution through their channels.

Topic prioritization will be based on input from the I&C Integration Committee. Preference will generally be given to products with greater near-term need/impact and/or broader applicability across reactor types and countries. Specific topics of interest will include the following:

- Computer-based training modules
- Failure analysis of digital systems
- Protecting against common-cause failure (CCF)
- Design and use of field programmable gate arrays (FPGA) in high-integrity applications
- Lessons learned and case studies based on operating experience in the United States, Korea, Canada, France, Japan, and other countries
- Human factors engineering (HFE) for digital interfaces
- Cyber security
- Application of risk methods to digital equipment
- Electromagnetic compatibility (EMC)
- Technical bases for resolution of regulatory issues (for example, CCF, HFE, cyber, risk, EMC, failure analysis)

Impact

Several factors drive the need for a comprehensive plan to resolve issues currently discouraging the implementation and successful application of digital I&C in nuclear plants, including the following:

Negative Experiences with Digital Implementations.—Digital upgrades at several plants have incurred significant unanticipated costs due to problems such as inadvertent plant trips, extended outages to correct startup issues, project delays, and cancellations. Key factors include inexperience with digital technology and the need for a paradigm shift to foster awareness of the issues and adapt utility and vendor processes, organizations, and skill sets accordingly.

Regulatory Uncertainty.—Licensing uncertainty on key issues has resulted in open-ended regulatory reviews with significant delays and increased project costs. Many plants now avoid digital implementations that involve unsettled regulatory issues or prior acceptance by the regulator.
Increasing Performance and Reliability Demands—Aging analog systems are becoming less reliable and more difficult to maintain, while expectations for equipment reliability and plant availability are increasing. Analog I&C plants have many single point vulnerabilities that could be eliminated using digital technology, with corresponding improvements in reliability and safety. Further, new operating conditions associated with power uprates could introduce functions and I&C performance requirements (for example, accuracy, response time) that require digital technology capabilities.

Obsolescence—In many cases, the old analog equipment has become difficult or impossible to maintain. Suppliers have discontinued support, spare parts are no longer available, and expertise on the old equipment has been lost through attrition and retirement. License renewal and extended fuel cycles exacerbate this problem. Further, while it is possible to extend the lives of some analog I&C systems for many years using enhanced maintenance practices and reverse-engineered replacement parts, this approach becomes more costly and less effective over time. Also, it typically cannot provide key digital technology benefits, such as performance improvements and elimination of single point vulnerabilities.

How to Apply Results

Upon completion of this work, nuclear utilities, their key equipment suppliers, and system integrators will be prepared to cost-effectively implement and maintain digital I&C in all types of plant applications. Digital I&C implementation will become routine, and most plants will have long range plans for I&C obsolescence management. Utility engineers will have convenient access to all needed guidance and training on the technical and regulatory issues. Utility processes and personnel will address the technical, programmatic, and ‘digital’ issues with predictable costs and schedules and with minimal risk of unexpected and undesired behaviors.

Also, the regulatory environment for digital I&C will be well-understood and stable; it will consider the safety significance of I&C in the context of overall plant risk and will allow I&C solutions that are practical, cost-effective, and well-engineered to meet safety and reliability goals. Regulatory reviews will have demonstrated cost and schedule predictability, with timely resolution of requests for additional information and issuance of safety evaluation reports. The review process will not create unacceptable project and schedule risks. EPRI products will include technical reports, guidelines, and companion training modules to help resolve the issues described above, addressing topics such as failure analysis, cyber security, software common-cause failure, human factors engineering, configuration management, and lessons learned from operating experience. EPRI will make its computer-based training (CBT) modules available for use through INPO-WANO on-line training systems by the end of 2011, with additional modules later if needed. Much of this material also will be applicable to new plants and will be used accordingly. EPRI also will provide technical input to inform regulatory issues under the existing EPRI/NRC memorandum of understanding.

Industry Oversight—Organizations such as INPO and World Association of Nuclear Operators (WANO) will make the EPRI digital I&C CBT modules available to utility engineers. They also will ensure that utility engineers maintain competence on digital issues, that utility processes are updated to address specific digital system concerns such as configuration management and common-cause failure, and that the processes are being applied appropriately. Industry operating experience will be monitored to detect emerging digital I&C issues and share lessons learned.

Regulatory Interfaces—Organizations such as the Nuclear Energy Institute will use EPRI results in assessing regulatory uncertainty concerns, such as the content and timing of information needed in licensing submittals involving digital upgrades and the possible update of existing regulator-endorsed guidance on common-cause failure in critical non-safety applications. Pilot application projects will be used to demonstrate the utility of proposed solutions and regulatory guidance.

Utilities/Suppliers—Utilities will apply EPRI and INPO guidelines and training materials along with relevant regulatory guidance and industry standards to develop and maintain proficiency in managing digital I&C, from specification to design evaluation, implementation, operation and maintenance, and obsolescence management planning. They will require suppliers, integrators, and contractors to apply these materials on an as-needed basis. In some cases, operating plants may elect to wait for key regulatory and project issues to be resolved via
new plant builds, and then apply the proven solutions and experience to reduce regulatory, cost, and schedule risks.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

I&C Productivity Improvements (supplemental)

Key Research Question
The nuclear power industry is concerned about its ability to maintain current high plant performance levels due to aging and obsolescence, knowledge drain, and fewer plant staff. Current plant operations are labor-intensive due to the vast number of operational and support activities required by the current technology. These concerns increase as plants extend their operating life.

To further improve performance while reducing human errors, nuclear plants increasingly focus on operations and maintenance costs, of which labor is typically the largest contributor. New productivity improvement capabilities with measurable economic benefits are needed so that a successful business case can be made for their use.

Approach
Improved and new instrumentation and control (I&C), human-system interface (HSI), information, and communications technologies can address concerns about cost-effectively maintaining current performance levels and enable shifts to even higher performance levels. This project will facilitate new technology implementation to improve productivity. Efforts will include demonstration of new technologies and how they can be used for plant and personnel productivity improvements, as well as providing pros and cons of their uses. Based on member input, required guidance for the application of technologies and pilot demonstration applications will be developed or requested to be developed.

Impact
Implementation of modern technologies can provide multiple benefits:

- Automation of appropriate tasks will reduce workload and human stress levels, remove human error-prone activities, and perform repetitive and time-consuming activities more effectively, allowing humans to better focus on essential activities requiring human capabilities.
- Simulation and visualization will support planning and decision-making, improve designs and facilitate early input from users, support development and testing, facilitate knowledge capture and training, improve job performance, and reduce the likelihood of human errors.
- HSIs and information technology will provide better user-friendliness, reduce the likelihood of human error, improve situation awareness, enable rapid access to data, and support decision-making.
- Communications technologies will enable collaborative activities, including rapid access to remote expertise, which will be even more effective with the use of visualization and simulation.

How to Apply Results
Members will apply the results of this project by learning how to implement advanced technologies for productivity improvements into plant modernization and workload definition plans. Potentially, pilot projects will be developed from which members can implement plant-specific applications.
Digital I&C Implementation (supplemental)

Key Research Question

Digital upgrades at several plants have involved significant unanticipated costs due to problems coping with various implementation issues. Examples of problematic issues with digital upgrades include unanticipated behaviors of digital equipment, software verification and validation, configuration management, evaluation of failure modes and effects, commercial grade dedication, and inadequate vendor oversight. Adverse impacts have included the following:

- Large increases in vendor and utility staff costs
- Significant project delays, as much as one or two refueling cycles
- Plant trips
- Extended outages to correct problems
- Additional engineering to correct problems
- Increased regulatory scrutiny

The problems are typically caused by inadequate knowledge and processes at the utility and its suppliers that prevent utility staff from managing the issues cost-effectively. In some cases, emerging instrumentation and control (I&C) and human-system interface (HSI) technologies include standard features that can eliminate or mitigate problems.

Approach

Many nuclear plant operators have requested EPRI assistance in improving plant programs for managing the problematic issues associated with digital upgrades. In some cases, industry guidance and good practices already exist, but have not been broadly communicated or widely practiced. In other cases, practical guidance for utility engineers is simply not available.

This project coordinates two meetings per year to address one or two specific application issues that are proving problematic for current digital upgrade projects. Topics include ensuring high reliability in non-safety systems, performing failure modes and effects analyses (FMEA) for digital systems, vendor interaction and oversight, and factory acceptance testing. Participants propose meeting topics, share plant experiences, discuss lessons learned, and identify areas that need additional research or guidance for utility engineers. Where appropriate, participants may develop or request new guidance and/or technical transfer mechanisms to provide practical, useful tools to plant engineers.

Impact

This interest group develops and promulgates practical guidance that will help utilities anticipate, detect, and mitigate potential problems before they result in expensive learning-curve events that can cost millions of dollars. The group promotes technology transfer of the latest industry and EPRI guidance on key issues and opportunities to identify current and future research needs for solutions that will smooth the transition to digital instrumentation and control (I&C) and ensure its long-term viability. Specific technical benefits include the following:

- Practices that will improve utility handling of problematic digital system issues
- Practices that will increase utility engineers’ ability to detect and manage weaknesses in suppliers’ designs and processes for key issues, such as failure analysis, software verification and validation, and software configuration management
- Technologies, strategies, and guidance that enable plant engineers to ensure long-term obsolescence management of digital systems using “design for replacement” approaches
- Practical guidance and training materials for utility engineers
How to Apply Results

Members will incorporate the lessons learned, guidelines, and training materials generated in this project into their processes, procedures, and training for digital upgrades.

I&C Reliability (supplemental)

Key Research Question

Aging or poorly maintained instrumentation and control (I&C) systems have resulted in numerous plant trips and power derates and have compelled nuclear plants to take repair or replacement actions to maintain plant availability and reliability. The Institute of Nuclear Power Operations has identified I&C components, in particular circuit cards, as an "Area for Improvement" at many plants. Because of the time and resources required to replace older I&C systems with modern systems, it may never make business sense in some instances to upgrade these systems. Plants will have to maintain existing systems long past the period where effective vendor support is available. In addition, replacement systems will require maintenance and life-cycle planning for eventual replacement.

Approach

Many nuclear plant operators have requested EPRI assistance in developing programs for managing I&C obsolescence focused on maintaining existing components. The I&C Reliability project provides a forum to exchange plant experience, best practices, and lessons learned. Such interactions support the implementation of effective I&C maintenance and life-cycle management technology and approaches for generic I&C maintenance issues that cut across multiple systems and/or suppliers. The group ensures that EPRI research and guidance documents respond to, and evolve with, the expanding knowledge base regarding I&C maintenance and life-cycle management.

Impact

I&C system and component failures are expected to increase as plants age, unless aging is carefully managed. This project provides many benefits:

- Broad cross-section of operating experience from which to capture lessons learned
- Identification of high-priority research activities to resolve I&C maintenance and life-cycle planning issues
- Opportunity to advise EPRI on I&C research to ensure activities address industry needs

How to Apply Results

Members apply the results of this project by adapting industry lessons learned into their plant I&C programs to more effectively maintain existing I&C systems and components.
Risk and Safety Management

Program Overview

Program Description

Risk and safety assessments provide information that enables nuclear plant owners to make technically sound decisions about plant design and maintenance and operating practices. These decisions contribute to safer and more cost-effective plant operation. Risk models and techniques are being used in a growing number of applications, including online maintenance, surveillance interval extensions, flexible allowed outage times, and risk-informed performance-based fire protection. Continuous refinement of methods and application approaches is necessary to ensure decisions best reflect industry operating experience, improved understanding of plant response, and state-of-the-art computational advances.

The Risk and Safety Management Program develops risk-assessment methods and the tools to implement them to enhance the safe and economic operation of existing and future nuclear power plants. These tools include software developed by the Electric Power Research Institute (EPRI) to assist utilities in performing detailed risk analyses necessary to achieve these objectives most effectively.

Research Value

Risk-informed performance-based approaches yield benefits for the regulator, the nuclear plant owner, and the public. Both the regulator and the plant owner can focus on issues truly important in protecting the health and safety of the public. The plant owner also gains operational flexibility and an opportunity for cost reduction. The widespread use of risk assessment has improved many aspects of plant safety and performance. These improvements have been driven by risk-informed initiatives, continued plant and equipment reliability improvements, and advances in probabilistic risk assessment (PRA) models. Risk and Safety Management Program members gain access to the following:

- Strategic roadmaps outlining research gaps confronting key issues—such as risk analysis of fire, seismic events, and other external hazards—and the collaborative actions needed to address these gaps
- Research results and technical input that foster a risk-informed, performance-based regulatory environment, including the significance determination process, the mitigating system performance index, and globally through periodic safety cases and license renewal
- Tools and methodologies that increase plant safety and reduce plant and resource requirements
- Shortened outages, fewer unnecessary shutdowns, reduced and focused inspections and testing, and appropriately reduced treatment of safety-related equipment that has low safety significance
- Robust, plant-specific framework for more focused and stable regulatory interactions

Approach

The Risk and Safety Management Program conducts research to facilitate the development of a risk-informed framework that can provide both operational flexibility and safety benefits to nuclear power plants. Operational flexibility encompasses online maintenance, flexible testing, flexible technical specifications, and enforcement discretion. Safety benefits include measurable risk reductions as well as intangible items such as improved safety focus.

Base research in the Risk and Safety Management Program develops improved methods and tools for conducting PRAs. Methods are improved by collecting and evaluating data and experience from risk practitioners at nuclear plants, regulatory agencies, and other entities who apply PRAs in a risk-informed framework. Tools are improved through fundamental research in numerical and logic modeling techniques and analysis of data for events such as loss of offsite power. Further, as nuclear plants are potentially exposed to a new class of externals hazards, including the crashing of commercial aircraft, high wind loads, toxic chemical releases, and various business and financial risks, advanced methods and tools will be needed to appropriately account for these risks in PRA models.
Base research also supports engagements with stakeholders to advance risk-informed methods within the regulatory context, through meetings, risk-informed discussion forums, and EPRI research activities. For example, this research area provides technical insight into the treatment of low-power and shutdown conditions and supports participation on global standards and working committees. Finally, through base research, EPRI supports continued development and refinement of its Education of Risk Professionals curriculum, which provides a structured approach for developing the new generation of risk practitioners.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate, and execute needed research among multiple entities. For the Risk and Safety Management Program, roadmaps have been developed to address the technical barriers confronting the development and acceptance of PRAs for fire and seismic events. Additional roadmaps will be implemented in 2012 to focus activities on external hazards (such as flooding and high winds), risk assessment for low-power and shutdown conditions, and the development of a next generation of software tools (integrated into the Phoenix program).

Through separate supplemental projects, nuclear plant owners can gain access to a wide array of risk-related software tools and user groups. Risk tools such as PRA DocAssist, GOTHIC, MAAP, HRA Calculator, and FTREX are maintained and improved through supplemental projects. Emerging tools such as Phoenix, an all-modes and all-hazards risk tool that will provide an integrated risk profile of a nuclear plant, are being developed through separate projects. User groups are available that address risk-informed regulatory treatment, the Risk and Reliability Workstation, and GOTHIC. Participants also have access to an on-site assessment of the potential benefits of an online maintenance program.

**Accomplishments**

EPRI’s Risk and Safety Management Program supports industry efforts to ensure risk-informed approaches can be used in making operational, maintenance, and regulatory decisions impacting nuclear power plants.

- Conducted a comprehensive research review to understand the technical basis of how nuclear power plant accidents evolve. This report, and the supporting research, provides a major contribution to informing regulatory decisions, forms the basis for analyzing the accident risks for the new generation of reactors, and will help ensure the safety of the currently operating nuclear plants over their lifetimes.
- Completed a long-term study of loss of decay heat removal and loss of inventory events during shutdown conditions in the nuclear industry, spanning 1990-2009, to discern potential reasons behind the observed increase in plant events during shutdown conditions in recent years.
- Evaluated the issues associated with setting minimum values for human failure probabilities and developed proposed guidance in the form of a set of values considered to be appropriate for various types of accident contexts addressed in probabilistic risk assessments.
- Developed the first in a series of computer-based training modules on the fundamentals of probabilistic risk assessment and risk-informed regulation. These modules provide a convenient and easy-to-understand mechanism for conveying risk principles.
- Developed functional requirements for the Phoenix software, an advanced risk code that would enable analysis of all modes and hazards and an integrated risk profile of the entire plant.
- Continued training program for the next generation of risk professionals. More than 75 people have completed the course, which reduces the qualification time to develop a contributing risk engineer.
- Provided improvements to the methods for developing Fire Probabilistic Risk Assessments in support of risk-informed regulation including transition to National Fire Protection Association (NFPA) 805.
- Developed guidance for performing an Internal Flood Probabilistic Risk Assessment (IFPRA). This guidance will help users meet the requirements of ASME/ANS RA-Sa-2009 while saving resources in development, maintenance, and review.
- Informed regulatory consideration of individual and emergency technical specification changes such as diesel generator “allowed outage time” modifications.
Current Year Activities

Risk and Safety Management Program research and development for 2012 will focus on enhancing risk-assessment methods and continuing the socialization of risk technology with both regulators and industry management and staff. Specific efforts will include the following:

- Continued improvements and enhancements of PRA and risk technology, most notably in the areas of fire PRA, seismic PRA, and other external hazards
- Investigation of approaches to address other modes of operation and other hazards, such as spent fuel stored on-site
- Continued development of the next generation of risk professionals through the Education of Risk Professionals course
- Computer-based training modules that address elements of PRA technology and use (including in support of risk-informed regulatory interactions) suitable for management and the end users of risk information
- Additional development of the advanced Phoenix software for risk assessment

Estimated 2012 Program Funding

$12.1 M

Program Manager
Stuart Lewis, 865-966-8014, SLEWIS@EPRI.com

Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P41.07.01.01</td>
<td>Probabilistic Risk Assessment for Internal Fire</td>
<td>This project supports development of PHOENIX, an all-modes and all-hazards advanced risk tool that provides an integrated risk profile of the plant. PHOENIX will be an advanced risk tool that enables users to address multiple hazards and modes of operation efficiently, obviating the current need for multiple tools. Additional planned capabilities include the ability to interface with inspection and automated log-books, remote equipment monitoring devices, and materials degradation matrices.</td>
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<tr>
<td>P41.07.01.02</td>
<td>Improvements to Seismic Probabilistic Risk Assessment</td>
<td>This project supports development of PHOENIX, an all-modes and all-hazards advanced risk tool that provides an integrated risk profile of the plant. PHOENIX will be an advanced risk tool that enables users to address multiple hazards and modes of operation efficiently, obviating the current need for multiple tools. Additional planned capabilities include the ability to interface with inspection and automated log-books, remote equipment monitoring devices, and materials degradation matrices.</td>
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<tr>
<td>P41.07.01.05a</td>
<td>Phoenix Technology Development (supplemental) (QA)</td>
<td>This project supports development of PHOENIX, an all-modes and all-hazards advanced risk tool that provides an integrated risk profile of the plant. PHOENIX will be an advanced risk tool that enables users to address multiple hazards and modes of operation efficiently, obviating the current need for multiple tools. Additional planned capabilities include the ability to interface with inspection and automated log-books, remote equipment monitoring devices, and materials degradation matrices.</td>
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<tr>
<td>P41.07.01.06b</td>
<td>MAAP 5 (QA) (supplemental)</td>
<td>This project supports the MAAP5 software code, which was developed to model the core, primary system, and balance of plant of a nuclear reactor following a postulated severe core damage accident. The software follows core melt and relocation, primary system thermal hydraulics, and fission product transport. This software is benchmarked against numerous physical experiments. It provides finer nodalization than MAAP4 and will be particularly useful for designing and licensing new plants. The software is developed under 10CFR50 Appendix B QA requirements for regulatory applications.</td>
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<td>P41.07.01.07</td>
<td>PRA Scope &amp; Quality (supplemental)</td>
<td>The PRA Scope and Quality project provides a vehicle for developing PRA guidance based on state-of-the-art technology. This project also provides a means for transmitting this technology to end users, through seminars, workshops, and webcasts.</td>
</tr>
<tr>
<td>P41.07.01.08d</td>
<td>PRA Documentation Assistant (supplemental)</td>
<td>This project develops software and compiles best practices to reduce the resource burden associated with PRA documentation and associated risk-informed applications.</td>
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<tr>
<td>P41.07.01.09</td>
<td>NFPA 805 and Fire PRA (Supplemental)</td>
<td>This project addresses issues impacting plant and regulatory actions related to fire PRAs, including the change process, change evaluations, fire-induced multiple spurious operations, fire-related human reliability analysis (HRA), operator manual actions, and non-conforming barriers. The Fire PRA User Group responds to technical and procedural questions on the use of fire PRA methods.</td>
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<tr>
<td>P41.07.01.10f</td>
<td>Risk-Informed Option 2 User Group (supplemental)</td>
<td>This project develops guidance to streamline the licensing process and define appropriate treatment practices for low-safety-significant structures, systems, and components. A project technical steering committee consisting of licensee personnel has been established to provide a forum for plant personnel to communicate issues, discuss resolution possibilities, review best practices, and benchmark against other plants' practices.</td>
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<tr>
<td>P41.07.01.11g</td>
<td>GOTHIC Advisory Group (QA) (supplemental)</td>
<td>This project develops software, procedures, and applications guidance for conducting three-dimensional analyses of reactor containment buildings under accident conditions. The user group provides guidance on new software features, as well as training and user support for the software.</td>
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<tr>
<td>P41.07.01.12h</td>
<td>HRA/PRA Tool User Group (QA) (supplemental)</td>
<td>This users group supports enhancements to and application of the HRA Calculator software tool. Due to the importance of human actions to nuclear plant safety risk and the impact of these actions on PRA results, the HRA User Group also provides training on HRA methods and the HRA Calculator software at least twice per year.</td>
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<tr>
<td>P41.07.01.13i</td>
<td>MAAP 4 (QA) (supplemental)</td>
<td>This project supports the Modular Accident Analysis Package Version 4 (MAAP4) software code, which models the core and primary system of a nuclear reactor following a postulated severe core damage accident. The software models accident sequence analysis through core heat-up, core melt and relocation, primary system thermal hydraulics, and fission product transport. This software is benchmarked against numerous physical experiments as well as other thermal-hydraulic and severe accident codes. The software is developed under 10CFR50 Appendix B QA requirements for regulatory applications.</td>
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<tr>
<td>P41.07.01.14j</td>
<td>Risk and Reliability User Group (supplemental)</td>
<td>EPRI has developed a diverse suite of computer software tools to support risk evaluations and plant operations, including fault tree codes (CAFTA), scheduling and risk mitigation tools (EOOS), and software for specialized analyses (for example, FRANX for fire PRA). This project provides software training, user support for these applications, and industry meetings that provide a forum for sharing results and methods among the user community.</td>
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</table>
### Project Number | Project Title | Description
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P41.07.01.15 | SQUG/SEQUAL (supplemental) (QA) | This project supports management and operation of the Seismic Qualification Utility Group (SQUG) and the Seismic Experience-Based Qualification (SEQUAL) program, which provide a cost-effective methodology for evaluating the seismic ruggedness of nuclear plant equipment without costly seismic shake table testing or analysis.
P41.07.01.16 | FTREX (supplemental) | This project supports continued development and maintenance of the FTREX software, which is widely used in the quantification of large fault trees. FTREX 1.0 was first issued in 2007, and faster, improved updates are released every 6 to 9 months.

#### Probabilistic Risk Assessment for Internal Fire (Roadmap)

**Key Research Question**

Fire can represent a significant contributor to the risk of a severe accident at a nuclear power plant. Effective decision-making related to managing risk in the regulatory arena relies on a realistic understanding of these risk contributors. The methods and tools currently used to assess fire risks, however, introduce conservatisms that can mask the most significant risk contributors and lead to inappropriate decisions. Improvements are needed to the data, methods, and tools for performing probabilistic risk assessment (PRA) for fires to produce meaningful results in an efficient manner.

**Approach**

Research activities to address fire risk have been identified through interactions with the nuclear industry and are summarized in an industry Fire PRA Action Matrix. The research activities are organized in four areas:

- **Initiation, detection and suppression.** Current estimates of the frequencies of damaging fires are significantly higher than is reflected in actual operating experience. Therefore, research is needed to improve this characterization. This includes development of a comprehensive fire events database that compiles information about experiences relating to fires in the operating history of nuclear power plants. The data collected will be evaluated to assess new frequencies for ignition and better treatment of detection and suppression. Associated research will enhance the understanding of incipient detection.

- **Damage assessment.** Current PRAs apply assumptions and correlations that are believed to over-predict the amount of heat released from a fire and the rate at which a fire of a particular type will grow. These predictions, in turn, cause risk assessments to reflect greater damage to equipment than may be realistic. Research into several of the physical aspects of fire development will be performed to ensure that the assessment of potential fire damage to equipment can be properly characterized in the PRA.

- **Plant impact, PRA scenarios, and quantification.** A number of different research tasks are underway to account for the damage caused by fire to be treated in a PRA model. This includes work to understand the types of system responses that might result from damage to electrical cables (both ac and dc), the way in which control room fires might evolve, and the treatment of human reliability. The refined understanding of the potential for damage from the previous research area, coupled with better methods for incorporating this understanding into the PRA models, will result in more realistic risk estimates.

- **Implementation activities.** Important activities necessary to implement the improved technical treatment of fire risks include updating relevant portions of the PRA Standard to reflect what is learned through new fire research; providing training in the proper use of methods for fire PRA; and participating in peer review of new methods as they are developed.
Impact

Several factors drive the need for more comprehensive and improved methods for fire PRA.

*Regulatory pressure.* Safety authorities in many countries require (or are considering requiring) fire PRAs to be conducted as part of the process of understanding the risks posed by operating nuclear power plants. In the United States, a movement toward performance-based regulation has led the nuclear power industry to conduct new fire PRAs for many plants. The methods and tools used in these assessments require further refinement to ensure that the results obtained reflect an appropriate characterization of risk. These improvements also are needed to allow meaningful results to be obtained far more efficiently than is possible with current methods. The extent to which risk-informed regulation has been implemented outside the United States varies widely, but many countries are considering programs similar to those in the United States or are including fire within the scope of their periodic safety reviews.

*Effective use of resources for risk management.* Beyond direct regulatory pressures, utilities must make effective use of limited available resources to address risks. An improved ability to evaluate the risks associated with fire is essential in ensuring that available resources are applied in a manner that results in proper decisions regarding operational activities and cost-effective safety improvements.

*Public perception.* Risk assessments performed using data and methods that reflect the current state-of-the-art yield results that can overstate risk, sometime by a large factor. PRAs completed using these limited methods can result in public perception that the risk of fire is too high. This perception, in turn, can further divert resources from more important issues.

How to Apply Results

EPRI will, in conjunction with other stakeholders, refine the data, tools, methods, and guidelines needed to support adequately realistic assessments of the risks associated with fire. These efforts will produce new databases and practical guidance for performing fire PRAs. The improvements will allow plant owners to perform fire PRAs that yield a more realistic understanding of risk with far less effort than is the case with the current methods and tools. This, in turn, will support more effective regulatory interactions and decision-making.

Improvements to Seismic Probabilistic Risk Assessment (Roadmap)

**Key Research Question**

Earthquakes have the potential to cause significant damage to nuclear power plants, and, therefore, constitute a major contributor to the risk of a severe accident. Recent research has increased estimates of the seismic hazard at nuclear power plants. Effective decision-making related to managing risk in the regulatory arena rely on a proper characterization of the risks associated with seismic events. Data refinements and analytical improvements are needed to obtain a more realistic understanding of the risk associated with seismic events.

**Approach**

More effective and realistic assessments of the risk associated with earthquakes require research activities that are coordinated with regulatory agencies and other organizations. Some of these activities have been ongoing for several years. Others are being highlighted or redefined as a result of the pilot seismic PRA completed jointly by EPRI and Dominion in 2010. The research activities are organized in four areas:

*Reassessment of the seismic hazard.* EPRI is engaged in significant research to better characterize the magnitude of earthquakes as a function of their frequencies of occurrence. These include an overall assessment of the hazard for the Central and Eastern United States, and participation in the resolution of generic issue GI-199. With regard to better implementation in seismic PRA, EPRI is conducting research to address statistical incoherence, seismic isolation, and the relevance and role of cumulative absolute velocity filtering for earthquakes of certain frequencies.
**Improved characterization of fragilities.** Fragility analysis is the assessment of the conditional probability of failure as a function of the intensity of a hazard. Necessary areas of improvement with respect to fragility analysis for seismic PRA include better coordination of the failure characterization with the response spectra for the site; refinement in fragility estimates to reflect more recent data from tests and actual experience; and better treatment of the impact on plant structures and equipment for soil sites.

**Seismic risk modeling and quantification.** Efforts are underway or are being initiated to improve the integration of the seismic hazard, fragility, and plant model to obtain better risk estimates. These improvements include how best to treat the correlation among seismic failure of similar equipment; adaptation of methods for human reliability analysis to reflect the conditions and context of earthquakes; and better methods for quantifying seismic risk, an area in which methods used traditionally for PRA are inadequate. These improvements will be tested through additional pilot studies.

**Implementation activities.** To make the most effective use of these research efforts, specific activities must be undertaken to ensure that they are incorporated into various programs. These activities include supporting the revision and refinement of the PRA Standard; interacting with regulators; and providing training to utilities in the performance of seismic PRAs.

**Impact**

Several factors drive the need for more comprehensive and improved methods for seismic probabilistic risk assessments (PRAs).

**Regulatory pressures.** Safety authorities in many countries require seismic PRAs to be conducted as part of the process to understand the risks posed by operating nuclear power plants (for example, as part of periodic safety reviews). In the United States, there are formal programs in place to apply risk information in a regulatory environment. Based in part on observations from a pilot seismic PRA completed recently by EPRI, improvements to current methods are needed for PRAs to meet the requirements of PRA standards in some areas. The extent to which risk-informed regulation has been implemented outside the United States varies widely, but many countries are reportedly considering programs similar to those in the United States.

**More effective risk management.** Utilities must make effective use of available resources to address risks. Seismic-related risks are subject to significant uncertainty, and utilities need to have a proper understanding of this uncertainty. An improved capability to evaluate the risk associated with seismic events is important to ensure that available resources are applied in a manner that results in proper decisions regarding operational activities and cost-effective improvements in safety.

**Public perception.** Risk assessments performed using data and methods that are not adequately realistic can lead to negative public perceptions. In the United States, inappropriate re-characterizations of the seismic risk for certain sites have already begun to become a public issue. Seismic risk estimates that do not reflect the most appropriate characterization have the potential to lead to public misperceptions that can divert resources from more important issues.

**How to Apply Results**

EPRI will, in conjunction with other stakeholders, refine the data, tools, methods, and guidelines needed to support adequately realistic assessments of the risk associated with seismic events. These efforts will produce a more coherent framework for seismic PRA, and a better and more coordinated set of technical methods. Owners of nuclear power plants will employ these methods and tools to develop an appropriate understanding of the contribution of seismic events to risk necessary for risk management and effective risk-informed interactions with regulators. At the same time, the results of this research will aid regulators in developing a better understanding of the risk associated with seismic events, necessary to avoid unwarranted regulatory actions and to support future risk-informed decisions.
Phoenix Technology Development (supplemental) (QA) (069739)

**Key Research Question**

As the use of risk technology permeates nuclear plant design, maintenance, and operation, risk practitioners need advanced tools capable of reflecting the current plant configuration and condition (including the operation state, ambient conditions, any degraded equipment or states). Greater regulatory attention to additional risks and hazards reinforces the need for an all-modes risk tool.

**Approach**

This project supports development of PHOENIX, an all-modes and all-hazards advanced risk tool that provides an integrated risk profile of the plant. PHOENIX will be capable of interfacing with inspection and automated log books, remote equipment monitoring devices, and materials degradation matrices to provide the most current information to operators and other decision-makers when these tools and interfaces become available.

PHOENIX highly leverages existing technology and its development is planned in several major phases over a 5-year period. The first phase is the integration of various probabilistic risk assessment (PRA) software for model building into a more powerful and consistent platform. The second phase is the addition of risk-monitoring phases and the addition of existing advanced modeling and quantification technology.

Follow-on phases include the addition of new technology capable of integrating additional databases and information archives, and external interfaces will be added.

**Impact**

PHOENIX represents the next generation of risk tools that are consistent, integrated, and capable of expansion beyond traditional risk analysis.

**How to Apply Results**

PHOENIX will be used by existing staff in a similar manner as existing risk tools and monitors.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

**2012 Products**

<table>
<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tbody>
<tr>
<td>PHOENIX - Integrated Platform - Release 1: PHOENIX highly leverages existing technology,</td>
<td>09/30/12</td>
<td>Software</td>
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<td>and the first step is the integration of various probabilistic risk assessment (PRA)</td>
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<td>software, both model building and risk monitoring, into a more powerful and consistent</td>
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<tr>
<td>platform. Release 1.0 provides the first version of the fully integrated risk tool</td>
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<td>platform, including risk-model development and risk-monitoring software.</td>
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MAAP 5 (QA) (supplemental) (050159)

**Key Research Question**

New regulatory applications and new nuclear plant designs introduce accident conditions and scenarios that the existing Modular Accident Analysis Package (MAAP4) can’t address. An improved version, therefore, is needed for robust safety analyses related to the post-accident behavior of the core and thermal hydraulics of the primary and secondary systems, including fission product release and transport.
Approach

This project supports continued development and maintenance of the MAAP5 software code, which was developed to model the core, primary system, and balance of plant of a nuclear reactor following a postulated severe core damage accident.

MAAP5 features improved nodalization of the reactor core, primary and secondary systems, and fission product inventory. It also contains models for the spent fuel storage pool.

The software follows core melt and relocation, primary system thermal hydraulics, and fission product transport. This software is benchmarked against numerous physical experiments. It provides finer nodalization than MAAP4 and will be particularly useful for designing and licensing new plants. The software is developed under 10CFR50 Appendix B QA requirements for regulatory applications. Both Windows and Linux versions of the software are available.

Impact

MAAP5 will be extensively used for the design of current and new generations of nuclear reactors. The analytical results generated by MAAP5 will be important in the final licensing of the new designs and the analysis of past reactor accident and events.

How to Apply Results

The software comes with a complete users manual, including solved examples. An applications manual has been developed to provide users guidance for specific, frequently encountered analyses. User Group meetings and training (both in person and web-based sessions) are provided.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

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<tr>
<td>MAAP5 CANDU: MAAP5 version to handle special geometries of CANDU reactor type</td>
<td>09/01/12</td>
<td>Software</td>
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<tr>
<td>MAAP 5.1: MAAP5 version to do advanced core damage modeling and spent fuel pool analysis</td>
<td>10/15/12</td>
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PRA Scope & Quality (supplemental) (068083)

Key Research Question

Risk technology and probabilistic risk assessments (PRAs) are currently being used in design, maintenance, and operational decision-making as well as in various regulatory interactions. A significant issue in the use of risk technology is the scope and quality, or technical adequacy, of the PRAs supporting these uses. For PRAs to have maximum utility, technology improvements must be captured and transmitted to PRA practitioners.

Approach

The PRA Scope and Quality project provides a vehicle for developing PRA guidance based on state-of-the-art technology. This project also provides a means for transmitting this technology to end users through seminars, workshops, and webcasts. The PRA Scope and Quality project solicits input from nuclear plant operators, regulators, and the public on the current technical issues facing risk-informed regulation. These issues are prioritized and resolved through a combination of research and development and consensus building among the
stakeholders. The result is a consensus guide that provides a clear, cost-effective, and consistent approach for addressing specific technical issues.

Impact
- Enable risk-informed applications
- Create consistent high-quality PRA and submittals
- Encourage stability in the regulatory environment
- Foster a safety and risk-informed culture

How to Apply Results
The PRA Scope and Quality committee meets several times a year to review, prioritize, and resolve PRA scope and quality issues. The research and development activities are accomplished using a collaborative process to develop issue-specific guidance, subject to peer review and pilot evaluation. Members apply the resulting risk guidance in plant-specific PRAs and risk-informed applications.

PRA Documentation Assistant (supplemental) (063062)

Key Research Question
Maintaining and upgrading a probabilistic risk assessment (PRA) is resource intensive. Documenting the PRA model changes is daunting and time consuming. Tools and technologies that minimize the manual handling of PRA documentation and data can reduce the overall resource burden associated with PRAs.

Approach
The PRA Documentation Assistant (PRA DocAssist) Project develops software tools and features for automating and managing the documentation process. This includes capturing key information about the model, developing the tools and processes that preserve cross-links to related information, and tracing the evolution of PRA assumptions and models. In addition, sharing of industry best practices on the configuration control of the PRA model and its associated documentation will lead to a more consistent industry approach and further resource reduction. The project will build on existing EPRI tools with input from a utility committee. Training, support, and a maintenance version of the code will be available to participants.

Impact
Reductions in the required resources through automation and process improvements can significantly increase PRA staff productivity. Furthermore, ready access to the documentation can reduce the resource burden associated with regulatory interaction on risk-informed applications (for example, Significance Determination Process [SDP], Mitigating Systems Performance Index [MSPI], and others) and peer reviewers, as well as enhance the ability to demonstrate compliance with PRA standards. An additional benefit of the project will be the ability to more quickly familiarize new staff, the Nuclear Regulatory Commission (NRC), and PRA peer reviewers with the PRA model and documentation.

How to Apply Results
The software and approaches developed in this project can be immediately implemented by the plant PRA staff by importing any existing documentation into the system. Further benefits are obtained by making the software part of daily use by the PRA engineers. This project provides the tools, techniques, and plant experience support to help members best customize the software configurations and work flows to meet the needs of their PRA models and staff capabilities.
NFPA 805 and Fire PRA (Supplemental)

Key Research Question

As the nuclear industry addresses current and emerging fire protection issues, and as some plants begin the transition to National Fire Protection Association (NFPA)-805, technical assistance is often needed to support the development of Fire Probabilistic Risk Assessments (PRAs) and risk-informed, performance-based fire protection. There is an ancillary need to provide a forum for communication among utilities going through the transition.

Approach

EPRI and the Nuclear Regulatory Commission (NRC) Research published a *Fire PRA Methodology Guide* (EPRI 1011989 / NUREG/CR 6850) in 2006. The methods in this report have been piloted, and a joint EPRI/NRC effort is in progress to revise the Guide. Among the issues being addressed to date are change process, change evaluations, fire-induced multiple spurious operations, fire-related human reliability analysis (HRA), operator manual actions, and non-conforming barriers. A report documenting the most up-to-date understanding of the behavior of DC circuits in the presence of fire will be produced in 2012. A Fire PRA User Group has been established to respond to technical and procedural questions on the use of fire probabilistic risk assessment (PRA) methods.

Impact

The cooperative effort between EPRI and NRC has resulted in the availability of the methodology guide and the resolution of several previously contentious issues. The project communication forum will allow for timely resolution of plant-specific issues as well as generic issues as they emerge in the transition process.

How to Apply Results

Results will be reflected in revisions to of the Guide and in individual EPRI-issue guidance reports. The first of these reports is EPRI 1013489, *Use of Fire PRA Methodology in Estimating Risk Impact of Plant Changes*. Other guidance documents will be used by utility personnel in their development of fire probabilistic risk assessments (1019259) and their implementation of risk-informed and performance-based fire protection.

Risk-Informed Option 2 User Group (supplemental) (061435)

Key Research Question

Regulations in the United States (10CFR50.59) allow plant owners to reduce the “nuclear special treatment” requirements currently imposed upon structures, systems, and components (SSCs) for those SSCs determined to be low-safety significant. Resources have been mainly dedicated to defining and conducting trial applications of risk-informed classification criteria, responding to Nuclear Regulatory Commission (NRC) comments, and supporting issuance of the final rule language and supporting guidance (for example, Regulatory Guide 1.201, Rev1). Now that the rule and accompanying guidance have been approved, there is a need to investigate, develop, and document appropriate “good practice” processes for plant-specific implementation of 10CFR50.69.
**Approach**
This project develops guidance to streamline the licensing process and define appropriate treatment practices for low safety significant SSCs. A project technical steering committee consisting of licensee personnel has been established to provide a forum for plant personnel to communicate issues, discuss resolution possibilities, review best practices, and benchmark against other plants’ practices. The technical steering committee will work with EPRI to prioritize the list of activities and provide input/direction for the program. EPRI will coordinate with other user groups and industry efforts, including licensees and owners groups, and will interface with other EPRI projects addressing equipment qualification, seismic issues, pressure boundary components, procurement to develop good practice documents, and technical basis.

**Impact**
Defining effective practices for classifying applicable SSCs and treatment practices for low-safety significant SSCs is an important part of achieving a successful 10CFR50.69 program. This step can result in significant cost savings while maintaining and/or improving the reliability and performance of SSCs.

**How to Apply Results**
Project participants will use the results to streamline classification of applicable SSCs and develop treatment processes for low-safety significant SSCs.

**GOTHIC Advisory Group (QA) (supplemental) (004444)**

**Key Research Question**
Software codes are used to perform thermo-hydraulic safety analyses of reactor containment buildings for regulatory applications. Feedback and input from users can help define needed improvements, enhance training effectiveness, and increase industry application.

**Approach**
This project develops software, procedures, and applications guidance for conducting three-dimensional analyses of reactor containment buildings under accident conditions. The user group provides guidance on new software features, as well as training and user support for the software.

GOTHIC Version 8.0 (QA) and prior versions of the software (QA) were developed and are being maintained by EPRI in a manner compliant with Title 10 of the Code of Federal Regulations Part 50 (10 CFR 50) Appendix B Quality Assurance and 10 CFR 21.

**Impact**
The GOTHIC code is widely used by utilities for performing thermo-hydraulic safety analyses of reactor containment buildings. The large user group results in ongoing refinement and modifications that enhance its value in addressing regulatory applications and responding to regulatory requests for additional information.

**How to Apply Results**
The Gothic User Group provides the software, upgrades, technical support, and training required to use GOTHIC.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.
HRA/PRA Tool User Group (QA) (supplemental) (049250)

Key Research Question

EPRI formed the Human Reliability Analysis (HRA) User Group and developed the HRA Calculator in response to member needs to promote quality and consistency in the use of HRA calculation methods and to consolidate these methods into a comprehensive software tool. The mission has expanded to include development of fire HRA methods, involvement in HRA benchmarking projects, and tracking of other research efforts in HRA. Continued development and maintenance of the software are necessary to sustain and expand its usefulness to the nuclear industry.

Approach

The HRA User Group has developed a software tool, the HRA Calculator, to support increased consistency in the use of HRA methods. The User Group seeks to maintain the software, improve its usefulness, and add capabilities where needed. The HRA User Group also provides training on the software at least twice each year. In addition, the User Group participates in the benchmarking of HRA methods and in other research areas aimed at improving HRA methods.

Impact

The HRA Calculator provides users with an effective software tool capable of applying a variety of HRA methods. The major methods implemented in the HRA Calculator are those developed by EPRI, including the Cause-Based Decision Tree Method (CBDTM) and the Human Cognitive Reliability with Operator Reliability Experiment (HCR/ORE) approach. The HRA Calculator also incorporates such methods as the Technique for Human Error Rate Prediction (THERP) and the Standardized Plant Analysis Risk-HRA (SPAR-H) method. The User Group continues to grow in its industry leadership role as recognized by the NRC and other entities seeking EPRI participation in the area of human reliability analysis.

How to Apply Results

The methods and software developed in this project can be immediately implemented by plant PRA staff responsible for performing human reliability analysis. Additionally, training on the HRA methods and the HRA Calculator software provides an efficient mechanism for members to expand capabilities to perform these evaluations.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.
MAAP 4 (QA) (supplemental) (003068)

Key Research Question
Nuclear plant owners must perform severe accident analysis in support of regulatory and safety applications. Such analyses depend on the ability to model and assess the behavior of the reactor core and fission products (for example, probability risk assessment [PRA] success criteria and accident sequence time and human reliability analysis). MAAP4 software and applications guidance were developed to fill these needs.

Approach
This project supports continued development and maintenance of the Modular Accident Analysis Package Version 4 (MAAP4) software code, which models the core and primary system of a nuclear reactor following a postulated severe core damage accident. The software models accident sequence analysis through core heat-up, core melt and relocation, primary system thermal hydraulics, and fission product transport. This software is benchmarked against numerous physical experiments as well as other thermal-hydraulic and severe accident codes. MAAP4 remains one of the few integrated thermal-hydraulic severe accident codes available. The software is developed under 10CFR50 Appendix B QA requirements for regulatory applications. Both Windows and Linux versions of the software are available.

Impact
Utilities use MAAP software to assess the Final Safety Analysis Report (FSAR) Chapter 15 analyses and to identify appropriate success criteria, perform accident sequence analysis, and identify human reliability timing in probabilistic risk assessments (PRAs). It has a large user group and is the code of choice for members to address regulatory applications and to respond to Nuclear Regulatory Commission (NRC) Requests for Additional Information (RAIs).

How to Apply Results
The software comes with a complete users manual, including solved examples. An applications manual has been developed to provide user guidance for specific, frequently encountered analyses. User group meetings and training (both in person and web-based sessions) are provided.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

2012 Products

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Risk and Reliability User Group (supplemental) (003888)

Key Research Question
Risk practitioners rely on tools such as the Risk and Reliability Workstation to achieve substantial efficiencies when performing risk analyses for probabilistic risk assessment (PRA) applications. Feedback and input from users can help define needed improvements, enhance training effectiveness, and increase industry application.

Approach
A suite of computer software tools has been developed to support risk evaluation and plant operations. This includes fault tree codes (CAFTA), scheduling and risk mitigation tools (EOOS), and software for specialized analyses (for example, FRANX for fire PRA). Guidelines are produced to aid the engineer, and regular training sessions are conducted. Meetings are held several times per year to promote training on the use of the software and provide a forum for sharing results and methods among peers.

Impact
The project has resulted in near 100% use of the Risk and Reliability Workstation software by U.S. plants and is widely used in international nuclear units and in other industries. The project provides a cost-effective method for members to provide input into and prioritize needed enhancements to the risk tools. It also provides a useful forum from which experiences from the user community can be shared.

How to Apply Results
The software, training, and user support available to members of the Risk and Reliability User Group is directly applicable by risk practitioners. Lessons learned from user group meetings can be incorporated into utility risk approaches as necessary. Software, training, and user support are available to members of the Risk and Reliability (R&R) User Group. Meetings held several times a year promote training on the use of the software and provide a forum for sharing results and methods among peers.

2012 Products

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Future Year Products

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<tr>
<td>EOOS 3.6: Updated version of EOOS software</td>
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SQUG/SEQUAL (supplemental) (QA)

Key Research Question
Seismic qualification of nuclear plant equipment and components remains an ongoing concern as additional data from seismic events are collected and analyzed. In the United States, Nuclear Regulatory Commission (NRC) Unresolved Safety Issue (USI) A-46 required seismic re-evaluation of the equipment in older operating plants to verify that its seismic ruggedness is comparable to that in newer plants in which equipment was qualified to newer standards.

Approach
The Seismic Qualification Utility Group (SQUG) was instituted to resolve NRC Unresolved Safety Issue A-46, “Seismic Qualification of Equipment in Older Nuclear Power Plants.” EPRI and the nuclear plant community successfully resolved the issue through development and implementation of an experience-based method that uses equipment performance data from power and industrial facilities that have undergone actual earthquakes. The SQUG/Seismic Experience-Based Qualification (SEQUAL) program continues to investigate earthquakes to add to the database, add new equipment classes, and develop and implement methods for experience-based seismic qualification of replacement equipment and parts. SQUG/SEQUAL also promotes the use of the experience-based methodology to its international members and to organizations beyond the nuclear community.

Impact
Provide a cost-effective methodology for evaluating the seismic ruggedness of nuclear plant equipment without costly seismic shake table testing or analysis.

How to Apply Results
Member engineers apply the SQUG methods to assess the seismic ruggedness of plant equipment; perform seismic evaluations of plant changes for heating, ventilating, and air conditioning (HVAC), overhead cranes, and piping; and qualify new and replacement equipment and parts.

FTREX (supplemental) (063727)

Key Research Question
As risk is increasingly employed in routine decision-making, the ability to rapidly produce results is needed. Advanced quantification engines such as FTREX are needed to support state-of-the-art analysis of large fault trees.

Approach
This project supports continued user support, development and maintenance of the FTREX software, which is widely used in the quantification of large fault trees.

Impact
FTREX is currently the fastest solution engine for solving PRA fault trees currently available from any source. It is especially useful for large models of systems and plants. It typically reduces the solution times from many hours to a few minutes of computer time.

How to Apply Results
FTREX is a simple add-in module for PRA-type software.
Advanced Nuclear Technology

Program Overview

Program Description

New nuclear power plants incorporating advanced light water reactor technology must overcome a number of regulatory, economic, technical, and social challenges prior to successful licensing, construction, and startup. Many of these challenges can be addressed through application of focused Electric Power Research Institute (EPRI) technical products and targeted deployment tools that minimize deployment risks.

The EPRI Advanced Nuclear Technology Program complements—and helps accelerate—industry activities aimed at enabling and building confidence in new nuclear plant deployment through coordinated work on cross-cutting issues. By building upon past industry operating experience and previous research and development (R&D) results, new nuclear plants can realize multiple benefits. These benefits include improved designs for safe and economic operation, implementation of optimized fabrication and construction practices, and more effective overall deployment of an inherently high-risk project.

Research Value

Research results from the Advanced Nuclear Technology Program increase confidence and reduce risks associated with developing advanced nuclear plant designs by incorporating current plant operating experience and results from focused research and development. The research addresses the issues that could impact the ability to license, construct, start up, and efficiently operate advanced light water reactors worldwide. Advanced Nuclear Technology participants gain access to the following:

- Strategic roadmaps outlining research gaps confronting key issues—such as configuration management, environmental fatigue, and digital instrumentation and control implementation—and the collaborative actions needed to address these gaps
- Materials management matrices for advanced nuclear plant designs that can serve as living documents for managing life-cycle material issues
- Equipment reliability knowledge and tools that can be incorporated into new plant designs to increase the potential for meeting business goals related to such issues as plant availability and sustainable high-capacity factors
- Refined methodologies for applying risk-informed pre-service and in-service inspection techniques to advanced nuclear plant designs
- Research supporting design and demonstration of next-generation nuclear plants, including small modular reactors and high-temperature gas reactors

Approach

The Advanced Nuclear Technology Program engages the utility and vendor communities to collaboratively identify and overcome the technical challenges confronting new plant deployment. The Program applies EPRI expertise in various disciplines to resolve common issues.

There are both base and supplemental portions of the Advanced Nuclear Technology Program. Base research covers various activities associated with advanced nuclear plant designs, including several projects targeting existing nuclear reactor designs around the world. Other base research projects address improved cooling water utilization and technical support for the development and demonstration of emerging small modular reactor designs.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate, and execute needed research among multiple entities. For the Advanced Nuclear Technology Program, roadmaps have been developed for implementing an optimized configuration management program for new plants and for addressing fatigue induced from environmental effects on primary reactor components.
Additional roadmaps are under consideration for small modular reactors, water utilization, unique nondestructive evaluation requirements for new plants, and cyber security considerations for new plants.

The supplemental portion of the Program focuses on four elements:

**Facilitating standardization across the new fleet**
Nuclear plant developers around the world are working to ensure standardization is factored into all aspects of new project development. However, while the designs may be standardized, many of the supporting systems will not be, including startup testing, balance-of-plant components, equipment reliability programs, operational procedures, and configuration management procedures. For example, EPRI is developing a standard configuration management approach to enable an automated, integrated, and interoperable configuration management program. The model will be an XML toolkit consisting of configuration management relationship taxonomy, supporting schemas, and rule sets.

**Transferring technology to new plant designs**
Lessons learned from existing plants and from EPRI’s 30+ years of research and development results are being incorporated into new plant designs to drive overall improved performance. Technology advances and lessons learned in materials, chemistry, equipment reliability, nondestructive evaluation, and fuel performance are being implemented into new plant designs. EPRI will continue reviewing available information with subject matter experts, designers, and utility representatives to define and prioritize requirements, guidelines, and assessments. For example, in 2010, EPRI began to assess chemistry control strategies at advanced plants based on the Design Control Documents, Combined Construction and Operating License Applications, and operating experiences (where they exist) against current water chemistry guidelines. This assessment forms the basis of future activities to address these differences and develop water chemistry guidelines applicable to the new plant designs.

**Ensuring top plant performance from start of operations**
Nuclear plant performance is a balancing act of equipment selection, material selection, design, operation, maintenance, management, and many other factors. Current financial models for evaluating new nuclear power plants are based on availability factors reflecting the fleet of existing nuclear plants. The research provides guidance allowing utilities to maintain high-availability factors at new plant startup. Products may address component specifications, commodity standards, and new instrumentation and control technology.

**Reducing the overall deployment risk and uncertainty**
Constructing, starting up, and working through initial operations of new nuclear power plants present many large, first-of-a-kind challenges. These challenges establish a deployment risk and uncertainty that affects the ability of utilities to get plants sited, approved, financed, and licensed. For example, EPRI is working with the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission to develop a new model that will provide nuclear facilities located in the Central and Eastern United States with an updated estimate of the sources of seismic events. This model will be used to evaluate both existing and potential new plant designs. The model is expected to be available later in 2011.

**Accomplishments**
The EPRI Advanced Nuclear Technology Program helps accelerate industry activities aimed at enabling and building confidence in new nuclear plant deployment. Recent accomplishments include the following:

- Secured membership from 21 U.S. and international utilities and critical nuclear industry vendors.
- Developed technical guidance for achieving higher levels of electromagnetic compatibility for advanced nuclear plant designs.
- Benchmarked use of modular design and construction techniques within and outside the nuclear power industry for application to new nuclear plant deployment.
- Formulated an initial methodology for risk-informed procurement, potentially enabling more off-the-shelf products to be sourced in new plant designs.
• Completed materials management matrices for four of the six advanced nuclear designs: Westinghouse AP1000, GE-Hitachi economic simplified boiling water reactor (ESBWR) and advanced boiling water reactor (ABWR), Toshiba ABWR, and Areva U.S. evolutionary pressurized reactor (EPR). These tools assist industry in identifying and considering materials issues and mitigation and management opportunities through design, component fabrication, plant construction, and initial operations and maintenance.

• Evaluated EPRI's *Fuel Reliability Guidelines* in the context of their applicability to new plant designs. Determined that utilities should apply the recommendations in nearly identical fashion, potentially with some unique considerations for each design.

• Summarized industry efforts to capture equipment reliability lessons learned during the design phase of a new plant project. The report compiles non-mandatory recommendations that reflect industry best practices.

• Identified critical welding and fabrication attributes for specific materials, assessed their effects on potential degradation mechanisms, and identified welding and fabrication process enhancements that can improve long-term asset management of new nuclear plant components.

### Current Year Activities

Advanced Nuclear Technology Program research and development for 2012 will continue its focus on proactive, risk mitigation/management projects for new plants, while expanding the program scope to include construction and startup activities. Specific efforts will include the following:

• Complete materials management matrices for all six of the new plant designs and address common issues identified from various projects

• Continue American Society of Mechanical Engineers (ASME) code case development and technical justification to allow for fitness-for-purpose under ASME Section III for Pre-Service Inspection (PSI)

• Evaluate the applicability of EPRI's *Water Chemistry Guidelines* to each of the new plant designs

• Develop utility requirements for small modular light water reactor technology

• Continue expanding international participation to increase collaboration with those organizations currently pursuing the development of new nuclear plants worldwide

Selected Advanced Nuclear Technology (ANT) program activities may be conducted in whole or in part in accordance with Title 10, Code of Federal Regulations, Part 50, (10CFR50), Appendix B, and may invoke 10CFR21 at the discretion of ANT member utilities or EPRI, when such action is deemed appropriate.

### Estimated 2012 Program Funding

$7.0 million

### Program Manager

Jeffrey Hamel, 650-855-2095, jhamel@epri.com

### Summary of Projects

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<th>Description</th>
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<td>Environmentally Assisted Fatigue Program (Roadmap) (QA)</td>
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Environmentally Assisted Fatigue Program (Roadmap) (QA)

Key Research Question
The ASME Code Section III design rules for piping and components have analytical requirements to prevent fatigue failures during service for a 40-year design life. The design analysis procedures for computing cumulative fatigue usage factor (CUF) incorporate the design cyclic stresses and fatigue design reference curves to safeguard against crack initiation for the materials of construction. Over the past 10 years, there has been extensive technical debate between ASME and the Nuclear Regulatory Commission on how to update the fatigue design curves to explicitly account for environmental factors that can affect the fatigue life and the CUF calculations. As a result, the ASME Code process has not been able to obtain a consensus position on the issue and, therefore, comprehensive code revision has been slow in development. Without industry action, NRC has published regulatory guidance, resulting in difficulties in demonstrating acceptable fatigue usage for both new plant design and license renewal approval (Reg. Guide 1.207, NUREG-6909).

Approach
The work is divided into three areas focused on short-term and long-term solutions:

Code Activities
EPRI will engage ASME Code working groups to develop new procedures that incorporate environmental factors for fatigue where required. The basic strategy is to first develop code cases that can be adopted by licensees, followed by code revisions. EPRI has formed an expert panel to review and advise the industry on technical issues and priorities. The goal is to minimize the impact of any new procedures and acceptance criteria for the plant owners while meeting the NRC regulation goals.

High-Energy Line Break Criteria
Postulated break locations for high energy piping must be identified for new plants as part of the initial design. For plants pursuing license extension, existing high-energy line break locations must be re-evaluated to determine if extended operation will impact existing pipe break mitigation hardware or add new locations to be considered for pipe break assessment. The current NRC selection process for identifying break locations uses criteria based on code stresses and local CUFs without a firm technical basis. The application of environmentally assisted fatigue (EAF) is likely to drive CUF above the current threshold (0.1) in many locations that otherwise would not be a concern for high-energy line breaks. There is no technical basis for this increase, and the resulting design changes would have negative impacts on construction cost, operations, dose, and inspections. Alternative criteria with appropriate technical bases are needed in order to avoid this outcome. EPRI will investigate the relative impact of CUF on pipe rupture and leakage and produce comparisons of fracture probability for different stress and cycle count combinations that result in equivalent CUF. The NRC also will participate in this activity through a cooperative effort. The short-term goal will be to provide a higher CUF criteria consistent with the inclusion of EAF; the long-term goal will be to provide a probabilistic approach, independent of CUF.

Co-Sponsored Projects
Final approval of code cases and proposed revisions to the code book will require cooperation among ASME, industry participants, and the NRC. EPRI will enter into an agreement with NRC to share development work in areas of mutual interest regarding EAF methods, data evaluation, and other cooperative tasks. A memo of understanding will be implemented and updated as required to define the shared work efforts. This research will address fatigue usage (cycling occurring prior to crack initiation), fatigue crack growth (crack extension after a fatigue crack initiates), and could include coordinating, developing, and monitoring any and all testing to provide the data needed in order to support the above work.
Impact

Regulatory Impact on New Plant Designs and License Renewal Plants

The lack of definite design rules creates uncertainty for both new plants and operating plants where design compliance must be shown for the extended operating period (significant uncertainty for potential 80-year life). To attain acceptable fatigue usage, design changes that increase design, construction, and operations costs without meaningful safety benefits may be required for previously certified designs, as well as designs currently under review by the NRC. Affected items in the design may include materials selection, piping thickness, fitting tolerances, and number and locations of piping supports. Additionally, for license renewals, there is uncertainty as to the requirements that may be imposed by NRC because the scope of locations requiring environmental fatigue analysis is open to interpretation.

Overall Cost to Plant Owners

The impacts on new and license renewal plants will directly affect the overall cost to plant owners in the form of design, re-analysis, and hardware modifications. For example, the selection of high-energy line break locations uses design CUFs in the screening criteria. Environmentally assisted fatigue application results in significantly higher CUFs for both new and existing plants. More detailed calculations will be needed to pass the screening criteria. When it may not be possible to pass the screening criteria, designers will need to add pipe motion restraints and jet impingement barriers, resulting in higher engineering and construction costs. For new plants with early design certification, any significant design changes would prompt fatigue requirements and require costly reevaluations and license amendments.

Global Interest

Several non-U.S. organizations have been actively following environmentally assisted fatigue issues because regulatory bodies worldwide tend to follow and take action consistent with the U.S. NRC, and/or ASME Code is often used as the governing design basis and operation for nuclear power plants. Moreover, several non-U.S. companies have been funding research and development on environmentally assisted fatigue solutions, including EDF, MHI, Rolls Royce, and KHNP.

How to Apply Results

Because this issue affects both operating and new plants, several EPRI programs will combine expertise and share final results. Upon completion of this work, EPRI will work through the ASME Code process to effectively implement code revisions that resolve the fatigue issue. These actions will include the following:

- Publication of reports and related documents that form the technical basis of code modifications in order to obtain code approval and regulatory acceptance
- Development of code cases that provide evaluation procedures for assessing fatigue environmental factors that are accepted by regulatory authorities
- Promoting an understanding of new procedures to provide for consistency of method and presentation by nuclear plant vendors, construction firms, and utilities (new and operating plant owners)
- Supporting ASME Section III and XI code revisions that permanently include EAF procedures within the body of the code

Regulatory bodies will participate in the development process and consider code changes related to environmentally assisted fatigue via their membership in ASME Section III and XI standards committees. A key objective is for NRC to evaluate guideline revisions for new plant design and license renewal, potentially endorsing the code cases and editions to the code through Regulatory Guides 1.84 and 1.147.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.
Low-Level Waste and Radiation Management

Program Overview

Program Description

Nuclear power plants face significant regulatory, economic, environmental, and public perception pressures with respect to low- and intermediate-level waste (LLW) management and personnel exposure to radiation. The safe processing, handling, and disposing of low-level waste requires a detailed familiarity with both technical and regulatory issues. Similarly, as regulatory limits on personnel exposure to radiation decrease, greater effort is needed to develop and demonstrate effective radiation protection and source-term reduction technologies.

The Low-Level Waste and Radiation Management Program investigates improvements to nuclear plant operational practices that can reduce risks associated with waste management and radiation exposure. The program develops guidelines and technologies for waste disposal volume reduction, dose and radiation field reduction, and nuclear plant decommissioning, resulting in lower electricity production costs, better informed regulatory oversight, and improved public perception. The program also develops technical guidance for early detection, mitigation, and remediation of groundwater contamination, an issue of increasing public concern and regulatory oversight.

Research Value

Effective management of low- and intermediate-level waste and radiation exposure enables nuclear plants to operate safely, cost-effectively, and with minimal risk to plant personnel, the public, and the environment. Research results are used by radiation protection managers to develop strategies for minimizing waste generation and reducing handling and storage costs. Research results are used by radiation protection managers to minimize radiation fields and reduce activity generation. Low-Level Waste and Radiation Management Program participants gain access to the following:

- Strategic roadmaps outlining research gaps and the collaborative actions needed to address these gaps. Active roadmaps address reducing worker radiation exposure, enhancing low-dose radiation science, optimizing storage and disposition of low-level waste, and improving radiological environmental protection.
- Technologies, assessments, and guidelines that can reduce solid and liquid waste volumes. LLW assessments, for example, have identified optimization recommendations valued at more than $75 million per year.
- New source-term reduction and radiation protection techniques that can reduce radiation dose. Source-term reduction studies have identified methods for reducing radiation fields by as much as 50% over 5 years.
- Technical guidance for risk-informed regulations in LLW, radiation protection, and groundwater protection that can address public safety and environmental stewardship concerns. Operational strategies for reducing the volume of Class B/C LLW could save the industry more than $27 million per year when fully implemented.

Approach

The Low-Level Waste and Radiation Management Program develops knowledge, guidance, and tools to reduce the risks and costs associated with waste management and radiation protection. The program also conducts plant assessments to provide expert support and to capture lessons learned that can be shared across the industry.

Base research focuses on developing the tools and technologies to reducing waste volumes, worker radiation dose, and groundwater impacts from nuclear plant operations.
• Low-Level Waste Research and Development (R&D): This research area supports the optimization of LLW management programs through advanced media testing, improved technologies and tools, safe and efficient on-site storage of low-level waste, and the development of technical bases for improved flexibility and risk-informed regulations for LLW disposal. Research activities focus on minimizing the generation of LLW, developing guidance for on-site storage, and examining alternatives to existing disposal regulations. For example, Electric Power Research Institute (EPRI) research identifies and conducts performance testing of media and processing strategies that may reduce LLW generation and optimize liquid radwaste processing system performance.

• Radiation Management R&D: This research area develops guidance, technologies, and operational practices to more aggressively reduce radiation fields (source term) and minimize worker dose to as low as reasonably achievable standards. Research activities are divided into two major areas: 1) source-term reduction, which focuses on minimizing radiation fields, and 2) radiation protection, which focuses on improving the use of dose reduction technologies and improving worker efficiency.

• Groundwater Protection R&D: This research area develops advanced strategies and technologies for improved management of situations involving radiologically contaminated groundwater. This project develops technical guidance for implementing site-specific groundwater monitoring programs geared toward mitigation, early detection, and remediation of groundwater contamination. Implementing these programs will enhance site knowledge and increase confidence and accuracy in stakeholder communications. EPRI also collaborates with industry and regulatory entities to provide technical data that can inform policies related to groundwater and environmental protection.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate, and execute needed research among multiple entities. For the Low-Level Waste and Radiation Management Program, roadmaps have been developed to address the technical barriers related to low-dose science, worker radiation dose, low-level waste disposal, and groundwater protection. Additional roadmaps will be developed as significant research gaps are identified.

Through separate supplemental projects, nuclear plant owners can gain access to a variety of interactive forums to discuss technical issues and share lessons learned in LLW management, radiation management, source-term reduction, and groundwater protection. Participants also can obtain on-site technical assessments to help plant personnel evaluate performance and fully benefit from research results.

Accomplishments

The Electric Power Research Institute (EPRI’s) Low-Level Waste and Radiation Management Program supports industry efforts to reduce the costs and regulatory burdens associated with low-level waste and to drive reductions in public, environmental, and personnel exposure to radiation. The Program develops and demonstrates innovative technologies, converts industry operating experience into practical guidelines, and explores alternative approaches for more effective LLW and radiation management.

• Issued groundwater and soil remediation guidelines that provide technical guidance for evaluating the need for and timing of remediation of soil and/or groundwater contamination from on-site leaks, spills, or inadvertent releases.

• Developed a more accurate methodology for estimating carbon-14 emissions from nuclear power plant gaseous effluent streams.

• Published a sourcebook that describes a two-pronged strategy for cobalt reduction: 1) a tabulated list of available cobalt reduction methods, with expected costs and estimated time required to observe radiation field reduction benefits; and 2) flowcharts for implementing a cobalt reduction strategy for boiling water reactor (BWR) and pressurized water reactor (PWR) plants.

• Issued guidelines for scaffold construction and management to optimize dose reduction opportunities during nuclear plant outages. Vertical access programs are consistently recognized as a significant contributor to high personnel exposure.

• Obtained regulatory endorsement for EPRI’s On-Site LLW Storage Guidelines, which provide consistent, industry-driven guidance for operation of on-site LLW storage facilities.
Source-term reduction recommendations implemented at Brown’s Ferry Unit 1 helped the unit achieve the lowest dose rates in the boiling water reactor (BWR) fleet following a restart. Based on analysis of industry pressurized water reactor (PWR) dose rate data, identified technical solutions that can provide measurable reductions in plant radiation fields. For example, zinc injection and electropolishing show strong benefit in reducing dose rates. Completed multi-year review of updated research on the health effects associated with low-dose radiation. Analysis concluded that the radiation damage/response paradigm should be expanded to account for increased complexity in biological response mechanisms. Results shared with regulatory community to inform revisions to radiation protection standards.

**Current Year Activities**

Low-Level Waste and Radiation Management program research and development for 2012 will sustain progress toward lower-cost waste handling and disposal, reduced worker dose, and improved detection and monitoring of groundwater. Specific efforts will include the following:

- Develop the technical basis for regulatory changes to low-level waste classification criteria
- Assess plant experience to determine if changes are needed to EPRI’s on-site LLW storage guidelines
- Collect and review plant radiation monitoring data to identify trends, evaluate performance of radiation protection technology, and identify research needs
- Develop and demonstrate radiation protection techniques and technologies for nuclear plant application
- Update EPRI technical guidance on groundwater protection
- Provide site-specific implementation support for source-term reduction technical guidance developed by the program

**Estimated 2012 Program Funding**

$4.5 million

**Program Manager**

Lisa Edwards, 469-586-7468, ledwards@epri.com

**Summary of Projects**

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<td>P41.09.01.01   (Roadmap)</td>
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The Groundwater Technical Strategy Group provides members a forum for discussing groundwater protection experiences, lessons learned, and advanced technologies. Members will have access to the Groundwater Strategy Group collaboration website and quarterly conference calls. Those utilities participating in the 3-year membership are eligible for one site-specific Groundwater assessment once during the 3-year period.

The LLW Technical Strategy Group provides a forum for discussing technical issues and sharing lessons learned regarding strategic LLW management. Members also receive expert technical consulting as part of their membership. The LLW Technical Strategy Group is available in 3-year and 1-year membership options. The 3-year membership includes one full LLW assessment once during the three-year period. Plants may elect to have a LLW Assessment performed at their facility independent of joining the LLW Technical Strategy Group. This can be arranged by contacting the project manager or account executive directly.

The Radiation Management/Source Term Technical Strategy Group provides an interactive forum for members to share and get expert advice in applying ALARA technologies and to gain insights on how to effectively reduce source term. Industry lessons learned and discussion of emergent issues will provide members with the most up-to-date information for making informed decisions on job planning and preparation.

**Technical Solutions for Reducing Worker Radiation Exposure (Roadmap)**

**Key Research Question**

The global nuclear industry is being challenged to aggressively revise programs and processes to reduce radiation exposure to workers while balancing increased maintenance work related to plant aging, fewer experienced staff, and increased radiation fields due to more aggressive core design, power uprates, cycle extensions, and other operational changes. In addition, radiation protection recommendations provided by the International Council of Radiation Protection (ICRP) Publication 103 are already being adopted in many countries. The Nuclear Regulatory Commission (NRC) has announced its intentions to revise U.S. radiation protection regulations in the next several years to align with the ICRP-103 recommendations. The most challenging change for U.S. plants may be the adoption of lower occupational dose limits, which could reduce the current limit of 5 rem/yr to as low as 2 rem/yr.

**Approach**

The project plan has four focus areas.

**Radiation Field Characterization:** This area aims to gain a better understanding of the impacts to radiation fields from changes to the operating environment (for example, chemistry, and core design) so that more focused radiation field mitigation techniques can be applied. Therefore, enhanced guidance to diagnose and characterize the impacts to dose rates from changes to operations, core designs, and water chemistry will be developed. Additionally, the area will aim to develop more relevant radiation field measurement data other than the current BWR radiation assessment and control (BRAC) standard radiation monitoring points (SRMP) to more accurately assess the benefits of source-term reduction and assess the impacts to worker dose. There also is a need to perform laboratory-based loop tests to enhance the fundamental understanding of surface activity incorporation so that more focused radiation field mitigation techniques can be developed.
Radiation Field Mitigation: This area will pursue technological solutions and collaborative activities to reduce dose rates. For example, the area will investigate new prefiltering techniques, decontamination technologies, and chemistry options to minimize the generation and transport of activated corrosion products.

Radiation Protection Technologies: This area aims to enhance worker efficiency and minimize dose through improved job planning and use of engineering controls, administrative controls, and personal protective equipment for situations where workers must work in existing radiation fields. For example, the program will work with vendors to streamline the use of temporary shielding through remote charging of tungsten balls. Additionally, efforts will pursue consistent application of radiation protection optimization techniques for high-dose tasks to ensure worker availability throughout the year.

Improved Dose Calculation: Efforts are needed to update the methodology for determining the effective dose equivalent (EDE) for external exposures. More accurate methodologies to calculate dose will improve the management of a worker's dose margin by up to 50%.

Impact

Regulatory: Worldwide, nuclear plant operators are required to maintain occupational radiation exposures to values that are as low as reasonably achievable (ALARA). With the adoption of ICRP-103, management of individual dose will become more challenging because the regulatory limit may decrease from the current limit of 5 rem/year to as low as 2 rem/year. It is anticipated that plant administrative limits will be reduced even further, to as low as 1-1.5 rem/year to ensure compliance with the regulatory limit. In the United States, these changes could affect approximately 1000 workers, many of whom have specialized skill sets important in maintaining plant operations and safety.

Performance: In pursuit of performance excellence, the U.S. industry (through the Institute of Power Operations) has committed to cumulative radiation exposure dose goals (cycle median) of 110 person-rem for BWRs and 55 person-rem for PWRs by the end of 2015. These dose goals are aggressive, especially for the BWRs, which have not met the current dose goal of 120 rem. Increased emphasis will be placed on reducing source term, improved ALARA planning, and on meeting the industry current and future goals. The World Association of Nuclear Operators has related goals to reduce collective dose.

Increased Maintenance: Outage scope has continued to increase due to plant aging, Alloy 600 mitigation, component upgrades or replacement related to license extension, power uprates, and increased safety requirements (for example, GSI-191 sump and BWR strainer modifications). The increased scope represents a challenge to controlling and reducing worker dose. For example, work related to a recent power uprate at a BWR unit resulted in an additional 30 rem for the outage.

Industry Commitment (RP2020 Initiative): The U.S. industry is committed to carrying out the objectives of RP2020 to reshape radiological protection at nuclear power plants to achieve significant improvements in safety performance and cost-effectiveness.

How to Apply Results

The immediate priority is to reduce individual dose by reducing the number of workers receiving greater than 2.0 rem/yr to 0.0 by 2015 (prior to estimated date of 2017 for implementation of the new regulation) through the optimization of high-dose work tasks and high-dose rate radiological work environments. EPRI will produce a wide spectrum of dose reduction and radiation field reduction technologies, techniques, and guidance that will require utility implementation. Supplemental programs are available to provide site-specific assistance with implementation of EPRI recommendations.

- EPRI is working with commercial partners to develop generic specifications for an advanced ALARA planning tool that utilizes three dimensional modeling and simulation. Additional development by each vendor will be needed to develop a fully functional, commercially available tool for implementation.
• EPRI recommendations for the use of advanced technologies for remote monitoring, location tracking, scaffolding, and shielding to improve worker efficiency and protection will require capital investment, infrastructure support, and possibly software changes and/or engineering review and approval.

• Technologies for radiation field mitigation may be costly; therefore, requiring advanced budgeting and coordination with other workgroups such as chemistry for implementation.

Updates to the effective dose equivalent (EDE) calculation for external exposure will require NRC approval prior to Industry use.

**Enhancing the Science and Communication of Low Dose Radiation Risk (Roadmap)**

**Key Research Question**

Improved understanding of radiation health risks is increasingly important to maintaining support for the continued operation of the global fleet of nuclear power plants and for building new plants. In recent years, greater scrutiny has been placed on the potential radiation health risks associated with 1) the management of groundwater leakage at nuclear power plants, 2) the alignment of worker and public exposures to more current global scientific standards, and 3) the management of radiological waste. A recent example of the heightened interest in these radiological risks stems from the National Academy of Sciences effort to update the study on cancer risks for populations living around nuclear facilities.

A dedicated research effort is needed to analyze the rapidly changing state of the science of low-dose research so that realistic risk models can be developed for nuclear power plant operational activities dealing with radiation. This improved understanding will provide the technical basis for communication of more representative risks to the public, regulators, and other stakeholders.

**Approach**

The EPRI Low Dose Research Program will perform research to 1) inform regulatory policies governing radiation protection by putting forth modern interpretations of low-dose risk models for consideration by the scientific committees responsible for developing international standards for radiation safety (for example, International Commission on Radiation Protection [ICRP], Biological Effects of Ionizing Radiation [BEIR] VII, and National Council on Radiation Protection and Measurements [NCRP]) and 2) support EPRI member utilities in communicating radiation risks to public stakeholders by providing the technical basis for standardized risk communication documents. The research project will achieve these goals through the following:

• Publishing, in peer-reviewed journals, first-of-a-kind analyses of DOE-funded, low-dose animal studies, focusing on effects from low-dose rates (potential collaboration with Pacific Northwest Lab). The analysis of this key dataset for low-dose rate effects will help fill the gap in being able to develop quantitative risk models that incorporate low-dose rate effects.

• Based on the results from this analysis and from the review of more recent studies focused on low-dose rates, propose an alternative, updated risk model based on an improved understanding of the range of possible dose and dose rate effectiveness factor (DDREF) values and uncertainties. Such a model will help inform future radiation safety recommendations. The results of this work also will be published in peer-reviewed journals.

• This improved understanding of low-dose risks will lead to the development of standard risk communication documents that are based on updated science and focused on the radionuclides found in nuclear power plant effluents (for example, tritium, C-14, Sr-90, Cs-137).

• Inform industry discussions and interpret the results of the National Academy of Sciences (NAS) study of cancer in populations living near nuclear facilities that has recently been commissioned by the NRC.

The EPRI Program will strongly leverage research results from domestic and internationally funded studies (for example, CRIEPI, MELODI, DOE Low-Dose Program, and others as they are identified) and incorporate them (as appropriate) into the EPRI review. Additionally, the program will seek international feedback and review of project developments and subsequent publications.
Impact

Global Performance Standards: Increasingly restrictive radiation protection standards can limit the beneficial use of radiation in society due to increased burdens associated with radiation protection and waste management. For example, the International Council on Radiation Protection (ICRP) provides international radiation protection standards based on the review and council interpretation of the basic science related to low dose health effects. The most recent recommendations, published in 2007 (ICRP Publication 103), are widely considered for regulatory adoption by each country. The review committee for these standards is expected to reconvene starting around 2017.

To enhance the credibility of any new or revised standards, it is important that the committee be fully aware and informed about all available scientific evidence and potential technical interpretations. The EPRI studies should be performed by an independent, distinguished committee of experts and the results published in peer reviewed journals.

Public Awareness: There are heightened public concerns about radiation risks due to recent events involving groundwater leakage, and more generally, any radiological releases from nuclear power plants. Understandable, science-based information that more accurately conveys the risks from such radiological releases can help better address such concerns. The information also can help inform and ultimately interpret the results of a National Academy of Sciences study of cancer in populations living near nuclear facilities that has recently been commissioned by the Nuclear Regulatory Commission.

How to Apply Results

The implementation of the EPRI results will lie mostly with the international committees and regulatory bodies (for example, ICRP, NRC, EPA) that are responsible for establishing radiation protection standards. These organizations will need to review the results within their processes and incorporate the EPRI concepts and recommendations as they deem appropriate. Utilities can incorporate the technical content from the EPRI research into their communication plans.

Optimized Storage and Disposition of Low and Intermediate Level Waste (Roadmap)

Key Research Question

Strategically, nuclear power plants should be prepared to operate for 60-80 years without any operational impact from low-level waste (LLW) storage. Utilities in most countries already must provide on-site storage for some or all of their radioactive waste. For instance, Mexico and Brazil have been subject to on-site storage of both low- and intermediate-level waste since beginning operation. In the United States, the Barnwell disposal facility stopped accepting out-of-compact waste, leaving more than 85% of the U.S. industry with no disposal pathway for Class B and C waste and resulting in the need for on-site storage. While new disposal pathways may become available, there is no certainty of their eventual operation. In some countries, actions to develop disposal pathways have not been started, have been blocked, or are subject to lengthy delays. On-site storage of LLW also concerns public stakeholders and recently has affected licensing activities for new plant builds.

The challenge, therefore, is to significantly reduce the volumes of LLW generated and to develop safe, efficient, and economic solutions for the on-site storage of radioactive waste for up to and including the life-of-plant. This can be done by reducing waste generation, managing waste that is generated to allow the use of available disposal pathways, building and operating storage facilities that are safe, economical, and regulatory compliant, and engaging in regulatory processes to ensure disposal regulations are technically justified and risk-informed while maintaining sensitivity to stakeholder confidence. Until such time as all members have access to disposal pathways for all LLW, there is an immediate need to reduce the burden imposed by storage of LLW.

Approach

To optimize low- and intermediate-level waste management and strategically prepare for 60 or more years of operation without impact from waste storage issues, three focus areas must be addressed, as described below.
The research will include interfaces with chemistry for proper implementation of operational strategies and with vendors for partnering to develop and deploy new technologies. The research will culminate in a set of tools available to the industry for use as applicable to their specific situations.

**Safe Storage:** Extensive research has already been conducted on the proper design of storage facilities, but will be updated as necessary based on newly imposed requirements and new operating experience that addresses efficiency and safety. This same guidance will be expanded to address storage issues associated with irradiated hardware. Long-term storage also will require evaluation of the best waste forms. Finally, a new focus area will investigate the concept of centralized storage facilities for plant fleets and between plant fleets to address the possibility of loss of all disposal pathways for long periods of time (which is a reality in some countries). Research results from this area will be of interest to all members, especially those with limited or no access to disposal pathways.

**LLW Minimization:** This area will provide guidance on how to economically reduce the generation of all waste streams. The immediate focus will be to reduce the generation of higher-activity waste streams for those plants that have access to disposal pathways for lower-activity wastes. EPRI will research the development of new operational strategies and new treatment technologies that concentrate higher-activity waste into smaller volumes. Continued work on the reduction of lower-activity waste streams remains important to those plants that have no access to disposal and are subject to storage of all LLW. Research results from this area will be of interest to all members, especially those with limited or no access to disposal pathways.

**Improved Flexibility in Disposal Regulations:** As the Nuclear Regulatory Commission begins the process of revising long-standing guidance for disposal regulations, EPRI will continue providing technical support for the revisions. In the United States, this will largely focus on the revision of the Branch Technical Position on Encapsulation and Concentration Averaging, which is expected to be revised during the 2011-2012 timeframe. In addition, a technical basis for revising 10CFR61 to make it risk-informed and performance-based will be developed to support the anticipated rulemaking process in this area in the 2012-2018 timeframe. Research results from this area will be of primary interest to U.S. members and for member countries still developing or revising disposal regulations.

**Impact**

LLW disposal costs continue to rise dramatically. Building, maintenance, and operation of storage facilities are resource intensive. Potentially escalating security requirements for radioactive materials, including stored waste, could significantly increase on-site storage costs. Funds for eventual disposal also may have to be accrued. LLW management strategies should target practices that generally reduce the generated volumes and favor waste streams with available and/or lower-cost disposal pathways.

**Stakeholder Confidence:** The lack of a disposal pathway for some low-level waste streams has been raised as a challenge during the licensing process associated with new plant builds. With the advent of the nuclear renaissance, it is critical that the nuclear industry manage low-level radioactive waste through effective use of available disposal pathways and efficient use of on-site storage in a manner that can be confidently and accurately communicated to the public as a safe operation.

**Regulatory:** Universal access to disposal pathways for low- and intermediate-level waste is a global concern. The disposal of low-level waste in the United States is principally governed by 10CFR61. This regulation is widely acknowledged as out-of-date, not reflective of current disposal practices, not risk-informed or performance-based, and not aligned with global regulations. The planned revision of these regulations provides a unique opportunity to develop a strong technical basis for risk-informing these regulations and associated guidance so that necessary restrictions are maintained, current disposal practices are credited, and updated science is used for risk assessment. Technical results also may be used by other member countries that are still developing or revising disposal regulations.
How to Apply Results

EPRI guidance on the operation of storage facilities should be adopted by stations at the onset of storage operations to ensure proper documentation is maintained and is regulatory compliant. Implementation of the storage monitoring requirements is primarily limited to the development of supporting processes and procedures, although inspection requirements may involve significant resource expenditures. Generally, plants have already made the capital investment for the actual storage facilities, but as the storage period extends, the need to build additional facilities should be planned for.

LLW minimization techniques developed through this research should be evaluated by each plant and adopted on a schedule that meets individual plant needs. In most cases, procedure revisions will be required for implementation, but little or no plant equipment changes will be needed. Advanced processing and reduction technologies may be implemented on-site or at centralized processing facilities depending on economics. Generally, these technologies will not require modification to plant equipment, but may involve new non-plant equipment, procedure, and contract / vendor changes.

When disposal regulations and guidance are updated, plants will need to update their programs as required. Changes should specifically be incorporated into waste characterization, storage, and shipping procedures and may involve re-characterization of stored waste. As guidance is developed that makes new processing options acceptable, the incorporation of these options into the existing waste program should be evaluated.

Radiological Environmental Protection (Roadmap)

Key Research Question

Nuclear power plants must manage effluents in a manner that protects the health and safety of the public and maintains releases within regulatory limits. Since the levels of radioactivity released by nuclear power plants are maintained at levels far below regulatory limits, stakeholder confidence and environmental stewardship are becoming larger components of these programs. For example, recent events have led several plants to undertake extensive remediation processes to address stakeholder concerns related to tritium leaks and spills resulting in soil and groundwater contamination. Also, as nuclear power plants continue to reduce the total radioactivity in monitored effluents, they will need to report radionuclides such as carbon-14 that were previously not reported because they did not represent significant fractions of the overall effluent radionuclide mixture. Current guidance for the estimation of dose from such obscure radionuclides in effluents is generic and may not apply to all nuclear power plant environments, leading some plants to report values that are not precise to their site-specific conditions. Due to the low impact on public health and safety, research and technology development on the minimization of low-level releases of radionuclides has been limited.

Approach

Groundwater Protection

- Update the EPRI Groundwater Protection and Remediation Guidelines to address industry program gaps identified through the Groundwater Protection Initiative (GPI) Peer Assessments and to identify opportunities for cost-effectively meeting the technical requirements of NEI 07-07
- Coordinate the risk assessment methodologies and guidance for buried piping and groundwater protection, resulting in a streamlined approach for risk ranking to meet the requirements of NEI 07-07 and NEI 09-14
- Provide technical guidance for using groundwater sample analysis methods to support faster identification of the source of a leak or spill
- Develop and demonstrate automatic groundwater monitoring and tritium separation technologies to optimize monitoring and remediation required to address stakeholder and regulatory concerns
Effluents Management

- Develop and validate precise calculation models for the generation, release, and dose to public of carbon-14 based on unit-specific reactor physics, design, and operation information
- Provide guidance for the precise calculation of carbon-14 dose to the public based on site-specific land use, geographic, and climate information
- Investigate other radionuclides in plant effluents from a risk basis to evaluate any potential impacts to humans and non-human biota as necessary

Impact

Public Perception: Although the small quantities of radionuclides released to the environment from recent industry events do not pose a human health and safety concern, public awareness has increased, prompting utility action. Public sensitivity to this issue could further increase as new plant licensing proceeds and as plants pursue life extension. Utilities will need to continue to reduce radioactive emissions from nuclear power plants by applying the as low as reasonably achievable (ALARA) principal and by being transparent and precise about informing the public about the sound environmental stewardship provided by the operation of the nuclear power plants.

Industry Initiatives: In response to increased stakeholder concern, the U.S. nuclear power industry has committed to implementing the “Groundwater Protection Initiative” to mitigate leaks and spills and to prevent off-site migration of groundwater contamination (per NEI 07-07 and NEI 08-08). The industry also has committed to the “Underground Piping and Tanks Initiative” to mitigate leaks from buried pipe systems and tanks (per NEI 09-14) at each nuclear power plant site. These initiatives highlight the need for more advanced monitoring, detection, and remediation technologies. EPRI provides the technical guidance and technologies needed to cost-effectively implement these Initiatives.

Regulatory: Current regulations are not a significant driver for groundwater protection. However, in response to stakeholder concerns, the U.S. NRC is currently evaluating its policies, regulations, and industry commitments related to groundwater contamination (for example, U.S. NRC Groundwater Task Force Final Report, June 2010). This evaluation may lead to new policies and regulations based on control of licensed materials and stakeholder confidence.

Nuclear power plants are required to report concentrations and associated doses of radionuclides that make up significant fractions of the total amount of radionuclides in effluent streams. As certain radionuclides are eliminated and as the total radioactivity of effluents is reduced, other radionuclides (for example, Carbon-14, Strontium-90, Cesium-137, and Chlorine-36) will likely need to be reported. Power plants need guidance to determine and understand the site-specific impacts of such radionuclides on humans and non-human biota.

How to Apply Results

Each nuclear power plant needs to implement the program described in the EPRI Groundwater Protection Guidelines and in the Soil and Remediation Guidelines to meet the requirements of NEI 07-07 and NEI 08-08. These guidelines address the risk ranking of systems, structures, components, and work practices; groundwater sampling programs; and procedures for responding to leaks and spills. Implementation of the guidelines requires the coordination of a multi-disciplinary group that includes experts on hydrogeology and plant engineering. In some cases implementation may require the installation of new plant equipment, primarily in the form of monitoring wells. The groundwater protection technologies developed by EPRI can be implemented to facilitate cost-effective groundwater characterization and remediation. Some will require vendor support for implementation. The EPRI Groundwater Protection Assessment programs provide support for utility implementation of EPRI research results.

The implementation of the EPRI method for estimating carbon-14 and other radionuclide generation and release will require reactor core design information (for example, neutron flux and mass of coolant) and information on the operation of various plant systems and components (for example, gaseous effluent release practices). The precise estimation of plant dose to the public may require an updated land-use census and environmental
sampling around the nuclear power plant. EPRI will provide the guidance and technologies to accurately understand and communicate impact of site-specific radiological effluents on human and non-human biota.

**Groundwater Technical Strategy Group (supplemental)**

**Key Research Question**

Leaks and spills from nuclear power plant operations can potentially impact site soil and groundwater throughout the life of the plant and the decommissioning of the plant. Experiences from other nuclear power plants can provide valuable insight into effective practices for addressing both technical and non-technical elements associated with groundwater protection. The Groundwater Technical Strategy Group provides a forum for sharing such experiences with industry colleagues and defining best practices applicable across the industry.

The Groundwater Technical Strategy Group is available in 3-year and 1-year membership options. The 3-year membership includes one full groundwater assessment once during the 3-year period.

**Approach**

The Groundwater Technical Strategy Group will be composed of members interested in sharing and discussing groundwater experiences and lessons learned, new technologies, and EPRI projects. Members will have access to the Groundwater Strategy Group Collaboration Website and quarterly conference calls.

The Collaboration Website is a digital portal where documents can be shared and forum discussions can be held. Relevant groundwater experiences, lessons learned, and technology information will be uploaded to the Collaboration Website for member access. Members also will be able to post their own experiences, lessons learned, and technology ideas to spark discussion with other members. Questions on groundwater topics also can be posted so that EPRI groundwater experts and other members can provide answers and associated information.

Conference calls on groundwater protection experiences, lessons learned, and technologies will be held each quarter (March, June, September, December.) These conference calls will be used to discuss promising technologies, key experiences and lessons learned, and EPRI projects.

As previously noted, those utilities participating in the 3-year membership are eligible for one site-specific groundwater assessment once during the 3-year period. This assessment is conducted on-site for both U.S. and international members and provides a detailed evaluation of how specific research results, technologies, industry experience, and industry best practices could be applied at a given plant. Typical Groundwater Assessment topics include assistance in implementing groundwater protection programs, assistance in conducting self-assessing compliance to NEI 07-07, demonstration of innovative technologies, and plant tritium modeling. Plants can choose one of these focus topics for their groundwater assessment. Plants may elect to have a groundwater assessment performed without joining the Groundwater Technical Strategy Group. This can be arranged by contacting the project manager directly.

**Impact**

By taking action against groundwater contamination, utilities will be able to allay stakeholder concerns about environmental protection. By implementing site-specific groundwater protection programs and the best technologies available for groundwater protection at nuclear power plants, utilities will be able to optimize costs and reduce waste due to groundwater monitoring and remediation:

- Improve relationship with communities, government, and regulatory agencies about the industry’s commitment to public radiation safety and environment protection
- Achieve cost savings at the decommissioning stage due to preemptive action during the operating stage
- Achieve cost savings due to advanced and efficient monitoring and remediation technologies
- Achieve cost savings due to prevention of radioactive liquid leakage to the environment
Utilities participating in the 3-year membership are eligible for one site-specific groundwater assessment once during the 3-year period. The assessment delineates actions with the largest potential benefit to the site and identifies potential gaps that, if closed, could provide economic, performance, and/or regulatory margin benefits.

**How to Apply Results**

Members can use the real-time information from the Groundwater Technical Strategy Group to implement improvements to their groundwater protection programs and to evaluate new technologies.

For utilities participating in the 3-year membership option, the groundwater assessment can be used to gain insights into the plant’s performance and into applying the EPRI guidance, technologies, and tools to the plant's advantage. The assessment team will develop a confidential site-specific report that details the strengths and gaps associated with the program and highlights prioritized recommendations and potential benefits. Later, generic results and lessons learned may be compiled in program reports for industry use. Plants may elect to have a groundwater assessment performed without joining the Groundwater Technical Strategy Group. This can be arranged by contacting the project manager directly.

**Low-Level Waste Technical Strategy Group (supplemental) (004514)**

**Key Research Question**

Nuclear plants frequently benefit from broader awareness of the LLW management activities practiced at other plants. The LLW Technical Strategy Group provides a forum for discussing technical issues and sharing lessons learned regarding strategic LLW management. Emerging technical issues include the Nuclear Regulatory Commission (NRC) Branch Technical Position on LLW concentration averaging; potential changes to 10CFR61; and LLW disposal site development, blending, encapsulation, solidification, and economics. Members also receive expert technical consulting as part of their membership.

The LLW Technical Strategy Group is available in 3-year and 1-year membership options. The 3-year membership includes one full LLW assessment once during the 3-year period. Plants may elect to have a LLW assessment performed at their facility independent of joining the LLW Technical Strategy Group. This can be arranged by contacting the project manager or account executive directly.

**Approach**

The Technical Strategy Group conducts periodic conference calls to keep membership appraised of emerging issues and to solicit input on industry responses to these issues. Webcasts are used to provide members with up-to-date status of LLW disposal options, presentations on new processing strategies, information on new regulatory notices, technical exchanges of lessons learned, and new ideas on cost control.

Members of the LLW Technical Strategy Group receive annual on-site expert technical consulting as part of their membership. This consulting time is typically used for continuous improvement of LLW program management strategies and for analysis of special projects. On-site consultation topics are scheduled with individual members. International members participating in the LLW Technical Strategy Group will receive their site-specific support remotely.

As noted above, those utilities participating in the 3-year membership are eligible for one site-specific LLW assessment once during the 3-year period. This assessment is conducted on-site for both U.S. and international members. Plants may elect to have a LLW assessment performed at their facility independent of joining the LLW Technical Strategy Group. Participants can select from several assessment focus areas: on-site storage, BC reduction, solid LLW, liquid LLW, and Liquid System Manager software installation. The utility also may specify a focus area currently challenging the plant. The utility and EPRI Project Manager will then work together to define the scope.
Impact

Participation in the Technical Strategy Group keeps members abreast of emerging issues surrounding LLW management and provides members with a forum for technical exchange.

Site-specific consulting time provides expert support for specific plant or corporate project requests. Individual plant and fleet strategies for LLW management are frequently evaluated with this support. Cost evaluations conducted during these consultations often identify significant cost-saving measures.

The on-site assessment provided for utilities participating in the 3-year membership (or arranged independent of the LLW Technical Strategy Group) evaluates how specific research results, technologies, industry experience, and industry best practices could be applied at a given plant. The assessment delineates actions with the largest potential benefit to the site and identifies potential gaps that, if closed, could provide economic, performance, and/or regulatory margin benefits.

How to Apply Results

On-site consultation time is used to ensure EPRI guidance is applied to emerging and critical plant-specific LLW management issues. Participation in periodic webcasts keeps members abreast of emerging issues in the rapidly changing climate surrounding LLW management and provides members with a forum for technical exchange. The LLW assessment helps plant personnel gain insights about their plant-specific performance and how to apply EPRI guidance, technologies, and tools to the plant's advantage.

Radiation Management/Source Term Technical Strategy Group (supplemental)

Key Research Question

While the industry’s annual collective radiation exposure continues to trend down, aggressive industry goals to further minimize station dose are challenging to meet in the life extension environment. The health of radiation protection programs is regularly assessed using cumulative exposure and exposure estimating, and utilities remain obligated to minimizing the impact of ionizing radiation on plant personnel.

Technology transfer and sharing of lessons learned can assist plants in driving greater implementation of EPRI guidance, technologies, and strategies related to ALARA and radiation management programs. The Radiation Management/Source Term Technical Strategy Group is designed to enhance the technology transfer between EPRI and member utilities through interactive forums, workshops, and expert assistance. Such engagement helps plants "take the research off the shelf and put it into the plant." Generic results and lessons learned will be used in base research and development (R&D) program products and reports.

The Radiation Management/Source Term Technical Strategy Group is available in 3-year and 1-year membership options. The 3-year membership includes a full radiation management assessment once during the 3-year period. Members may elect to have a radiation management assessment performed at their plant independent of the Radiation Management / Source Term Technical Strategy Group. Contact the project manager or account executive to make these arrangement directly.

Approach

The Radiation Management/Source Term Technical Strategy Group provides an interactive forum for members to share and get expert advice in applying ALARA technologies and to gain insights on how to effectively reduce source term. Industry lessons learned and discussion of emergent issues will provide members with the most up-to-date information for making informed decisions on job planning and preparation. This comprehensive approach to managing radiation exposure will help educate and cross-train personnel with differing backgrounds on topics highly relevant to dose minimization and management.

The Strategy Group focuses on best practices, advanced technologies, the most efficient implementation options of ALARA source-term reduction technologies, and cost-effective sustainable ALARA program success. The group typically sponsors workshops on topics of interest to dose management such as source-term
reduction and advanced shielding applications. These workshops bring together plant personnel and service
providers to ensure members are kept abreast of emerging technologies and have the advantage of a peer-to-
peer forum for exchanging ideas and information. Results obtained from these workshops and information
exchanges will be integrated into a summary report that will provide Strategy Group members with the
benchmarking information they would need to develop a site-specific dose reduction strategy. The information
also will supplement research performed within the EPRI base-funded Radiation Management Program.

As noted above, those utilities participating in the 3-year membership are eligible for one site-specific radiation
management assessment once during the 3-year period. This assessment is conducted on-site for both U.S.
and international members and provides a detailed evaluation of how specific research results, technologies,
industry experience, and industry best practices could be applied at a given plant. Members may elect to have a
radiation management assessment performed at their plant independent of the Radiation Management / Source
Term Technical Strategy Group.

Impact

Plants that have implemented relevant EPRI technology in the ALARA area have realized significant benefits in
personnel exposure control. EPRI’s radiation field control technologies provide a menu of techniques to reduce
out-of-core shutdown radiation fields and for continuing development of worker risk-minimization techniques that
target increased worker productivity. The Radiation Management/Source Term Strategy Group provides an
opportunity to drive exposure performance success that, in turn, can impact regulatory requirements, insurance
premiums, and benchmarking metrics.

Utilities participating in the 3-year membership are eligible for one site-specific radiation management
assessment once during the 3-year period. The assessment delineates actions with the largest potential benefit
to the site and identifies potential gaps that, if closed, could provide economic, performance, and/or regulatory
margin benefits.

How to Apply Results

Members sponsor annual meetings and workshops that address key ALARA and radiation source-term issues.
These workshops provide an interface for peer-to-peer and utility-to-service-provider interactions on topics of
specific interest to dose management. Lessons learned and insights are brought back to the plant for
implementation.

Members also have access to Radiation Management/Source Term Technical Strategy Group industry
experience databases and reports. These mechanisms enable radiation protection personnel to more effectively
address technical ALARA issues and implement worker risk-minimization techniques.

For utilities participating in the 3-year membership option, the full radiation management assessment can be
used to gain insights about the plant’s performance and how to apply the EPRI guidance, technologies, and
tools to the plant’s advantage. The assessment team will develop a confidential site-specific report that details
the strengths and gaps associated with the program and highlights prioritized recommendations and potential
benefits. Later, generic results and lessons learned may be compiled in program reports for industry use.
Decommissioning and Technology Development

Program Overview

Program Description

Decommissioning a nuclear power plant requires expertise in safe industrial dismantling and demolition, nuclear power plant operations, radiation protection, radiological characterization, environmental protection, radwaste management, and other specialized disciplines. Because of the complex, multi-disciplinary activities involved in decommissioning nuclear power plants, experience must be captured to serve as guidance for ongoing and future decommissioning projects around the world. Also, experience shows that various events and actions that occur during operations, such as soil and groundwater contamination, can impact decommissioning waste generation, cost, and schedule. Understanding these impacts and operating the plant to minimize impact on decommissioning can benefit the entire nuclear power plant life cycle.

The Decommissioning and Technology Development program provides a structured approach for capturing lessons learned from decommissioning efforts and incorporating them into guidance for the entire nuclear power industry. Several nuclear power plants, for example, have gained experience in addressing both technical and regulatory challenges. These challenges include minimizing contamination, final site surveys and site release criteria, license termination planning, transition of regulations from operation to decommissioning plants, plant structure demolition, reactor vessel segmentation, and waste disposal.

Research Value

The Decommissioning and Technology Development program develops guidance and technologies that can assist in the safe, cost-effective decommissioning of a nuclear power plant. Program participants gain access to the following:

- Data and information leading to safe decommissioning with lower costs and risks
- Enhanced planning tools to guide decommissioning
- Lessons learned from decommissioning activities at other plants
- Application results from the use of advanced technology
- Guidance on unresolved issues in groundwater and soil protection and remediation, low-level waste management, site characterization, radiation dose modeling for site release, and license termination plans

Approach

The Decommissioning and Technology Development program evaluates industry practices to distill generic guidance that nuclear plant owners can incorporate into decommissioning plans. Participants use lessons-learned reports and advanced technologies to operate plants to minimize downstream impacts on decommissioning and to establish and implement efficient decommissioning programs at plant sites. Participants also enhance technology transfer through participation in Electric Power Research Institute (EPRI) decommissioning workshops and plant-specific decommissioning support meetings.

- Archive experience and lessons learned related to decommissioning regulations and technology
- Assess strategies for operating plants that could minimize subsequent site contamination and waste generation during decommissioning
- Identify critical elements associated with developing and maintaining an effective decommissioning plan
- Evaluate options for disposing wastes from decommissioning plants
- Develop and demonstrate advanced technologies and improved methodologies for decommissioning
- Anticipate and address needs arising from premature (unplanned) shutdown of nuclear units
The Decommissioning and Technology Development program is a supplementally funded activity.

**Accomplishments**

The Decommissioning and Technology Development program supports activities to operate nuclear power plants to minimize impacts on decommissioning and to safely and cost-effectively decommission nuclear power plants. EPRI has archived best practices, lessons learned, and technology experiences ranging from decommissioning planning and execution to final site release and license termination. This information is available through technical reports and through direct interaction with decommissioning experts.

- Evaluated the use of in-situ gamma spectroscopy for characterizing potential radionuclide contamination of soil, concrete, and bedrock prior to site release.
- Defined a trial program to evaluate a new technology called "nibble and vacuum" for removing reactor graphite by remote in-situ size reduction and vacuum transfer.
- Developed guidance on program change management during decommissioning. The guidance defines decommissioning in terms of a sequence of major milestones and then identifies the plant programs, associated plans and actions, and staff for each milestone.
- Documented full system chemical decontamination experience at Spain's José Cabrera Nuclear Power Plant, capturing new practices and useful lessons learned.
- Captured lessons learned and good practices involved in managing radiologically impacted soils, sediments, and bedrock at decommissioning nuclear power plants.
- Developed decommissioning pre-planning and planning guidance reports and waste management software tools.
- Compiled decommissioning experience reports on reactor vessel and internal segmentation, concrete radiological characterization and remediation, final status survey and license termination, and groundwater protection.

**Current Year Activities**

Decommissioning and Technology Development program research and development for 2012 will focus on continued collection and evaluation of industry decommissioning experience to derive effective guidance for future plant decommissioning efforts. Project topics may include the following:

- Software for the automatic estimation of the radiological inventory for the dismantling of nuclear facilities
- Technical justification for the development and application of derived concentration guidance levels
- Decommissioning lessons learned, experiences, and their impacts on decommissioning costs and other resources
- International experience in segmentation of reactor internals and vessels
- Software for the collection and analysis of site characterization and final status survey data to show compliance with site release criteria
- Waste source term assessments and updated base material specifications for activated metals to assist with decommissioning waste management
- Behavior of chlorine-36 and tritium in irradiated graphite wastes

**Estimated 2012 Program Funding**

0.7 million

**Program Manager**

Sean Bushart, 650-855-8752, sbushart@epri.com
Summary of Projects

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<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P41.09.02.01</td>
<td>Decommissioning Technology Development (supplemental)</td>
<td>The EPRI Decommissioning Technology Development project provides technical support and technology development for cost-effective, safe, and environmentally sound decommissioning of nuclear power plants.</td>
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Decommissioning Technology Development (supplemental) (052386)

Key Research Question

Nuclear power plant decommissioning requires expertise in safe industrial dismantling and demolition, nuclear power plant operations, radiation protection, radiological characterization, environmental protection, radwaste management, and other specialized disciplines. U.S. and international experience in decommissioning nuclear power plants can guide decommissioning efforts around the world. Several nuclear power plants have gained experience in both technical and regulatory challenges, such as final site surveys and site release criteria, license termination planning, transition of regulations from operation to decommissioning plants, plant structure demolition, reactor vessel segmentation, and waste disposal. Applying lessons learned and experiences from previous projects to the planning and execution of current and future projects will provide opportunities to optimize costs, increase safety, and reduce waste and impact on the environment.

Approach

This project assists members in minimizing the cost and risks of decommissioning through enhanced planning, applying lessons learned from other retired plants, and using advanced technology. Guidance is developed on unresolved issues in low-level waste management, site characterization, radiation dose modeling for site release, and license termination plans. Key project objectives include anticipating and addressing the needs arising from premature (unplanned) shutdown of nuclear units and capturing the lessons learned from current decommissioning work. Best practices, lessons learned, experiences, and recommendations are documented in EPRI technical reports. This information also is available to members through direct interactions with decommissioning experts at technical workshops and through site-specific member support. As new technologies are developed to address challenges from past decommissioning projects and as new technical challenges create the need for new technologies, EPRI works with technology vendors and utilities to evaluate and demonstrate technologies for application in nuclear power plant decommissioning.

Impact

The successful decommissioning of nuclear power plants demonstrates responsible management of a nuclear power plant's complete life cycle. Applying the lessons learned and experiences of previous decommissioning projects will allow current and future nuclear power plants to plan and execute successful decommissioning projects that are cost-effective, safe, minimize waste, and minimize impact on the environment, while increasing public acceptance and support for nuclear power. Potential benefits include the following:

- Access to experience and lessons learned related to decommissioning regulations and technology
- Reduced costs in developing and maintaining an effective decommissioning plan
- Reduced costs associated with disposing wastes from decommissioning plants
- Reduced implementation costs for advanced decommissioning technologies
How to Apply Results

Members use lessons-learned reports and advanced technologies to establish and implement efficient decommissioning programs at plant sites. Members also enhance technology transfer through participation in EPRI decommissioning workshops and plant-specific decommissioning support meetings. Plant-specific decommissioning support meetings allow members to tailor technical support to site-specific concerns.
Water Chemistry

Program Overview

Program Description

Water chemistry conditions at nuclear power plants can impact corrosion rates, fuel performance, and radiation management. In light of increasing demands on chemistry staff and reductions in the number of staff, nuclear power plants are challenged to maintain effective water chemistry control. Improved water chemistry can reduce the frequency of transient fault conditions and overall impurity concentrations. However, continued improvements are needed to optimize water chemistry and balance the resulting impacts and improvements on system materials corrosion, fuel performance, and radiation fields.

The Water Chemistry Program develops and updates water chemistry guidelines for nuclear reactors based on industry research and plant experience. The program also develops water chemistry optimization tools to mitigate corrosion, achieve, and maintain design fuel performance standards and minimize plant radiation fields.

Research Value

The Water Chemistry Program develops technical guidance that can be incorporated into nuclear plant chemistry procedures. Research results help nuclear plants create strategic water chemistry plans for maximizing plant availability and cost efficiency in a manner consistent with safety and regulatory requirements. Water Chemistry Program members gain access to the following:

- Cost-effective chemistry optimization tools and techniques to improve plant availability and safety.
- New chemistry applications through first-of-a-kind technology demonstrations. For example, field demonstration of a polyacrylic acid dispersant showed a 50% reduction in corrosion product fouling, increasing steam generator availability.
- Software-enabled improvements in chemistry control, diagnostic capabilities, and staff productivity.
- Enhanced technology transfer through plant-specific collaborations.
- On-site assessment support to benchmark plant chemistry controls and identify opportunities to optimize chemistry protocols.

Approach

The Water Chemistry Program combines basic and applied research with industry operating experience to develop guidance and technologies for nuclear power applications. The Program provides a comprehensive suite of water chemistry tools, including guidelines, new operating and monitoring technologies, chemistry control and assessment software, user groups, and on-site assessments.

Base research activities encompass research related to chemistry guidelines, first-of-a-kind technology demonstrations, and software development.

- Chemistry Guidelines: This research area provides up-to-date guidelines, develops leading technologies, and performs assessments in support of safe, reliable, and optimized water chemistry operation. The key products are a series of water chemistry guidelines for boiling and pressurized water reactors based on ongoing research and field experience. Each guideline is a consensus document developed by industry experts to optimize water chemistry programs and control methods. Guidelines are formally reviewed on an annual cycle and generally revised on a four-year cycle. Much of the research focuses on water chemistry control methods, improved monitoring techniques, and chemical additives to control corrosion, reduce radiation fields, and maintain fuel performance.
• First-of-a-Kind Technology Demonstrations: Implementing new chemistry technologies typically requires demonstration at a plant site under controlled and monitored conditions. This project develops and tests new chemistry additives, new analysis methods, new instrumentation, and application guidelines on how to efficiently use new chemistry technology. Electric Power Research Institute (EPRI) expertise and management is applied to ensure the data from these demonstrations is objective and can properly inform application sourcebooks and technology commercialization decisions.

• Software Development: Nuclear power plants must meet strict system performance guidelines to ensure pressure boundary integrity, fuel performance, and minimized radiation fields. Robust calculation tools that are consistent with industry practice can help achieve these goals. The results from ChemWorks software programs are used in a variety of chemistry system evaluations, including high-temperature pH calculations for reactivity control in pressurized water reactors, hideout return evaluations for the secondary side of the steam generator, and estimating corrosion product inventory during shutdown. From these predictions, chemistry personnel can assess corrosion control, guide life-cycle strategies, and optimize overall costs.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate, and execute needed research among multiple entities. For the Water Chemistry Program, roadmaps are under development for chemistry guidelines for new plants, auxiliary system chemistry optimization, source term reduction, dispersant application for fouling mitigation, and the ChemWorks software program. Additional roadmaps will be developed as needed.

Through separately funded projects, participants gain access to additional research activities. For example, nuclear plants can participate in user groups focused on improvements and lessons learned from the ChemWorks and web-based Smart ChemWorks software systems. Implementation and evaluation support for a number of chemistry technologies—including startup hydrogen injection, feedwater iron optimization, boiling water reactor (BWR) cycle chemistry, secondary cycle pH optimization, zinc injection, and dispersant injection—also is available. Additional user groups provide access to utilities with common interests in resins, filters, zinc application, and overall chemistry optimization.

Accomplishments

Electric Power Research Institute's (EPRI's) Water Chemistry Program supports nuclear power industry efforts to improve water chemistry control and minimize water chemistry impacts on other plant systems and components. Water chemistry research provides members with the guidance and technologies to improve operational flexibility, reduce operations and maintenance costs, reduce dose, and reduce material degradation risks.

• Completed the latest EPRI benchmarking assessment of reactor coolant system zinc addition using available plant data. In general, zinc concentration is relatively unaffected by power transient and associated minimal temperature changes.

• Compiled summary report of the intergranular stress corrosion cracking mitigation performance of 44 BWRs with or without noble metal chemical addition or On-Line NobleChem. Results are categorized by chemistry regime and include data from the most recently completed and current operating cycles.

• Supported first continuous operational application of a chemical dispersant to reduce sludge accumulation in steam generators. Dispersant use maximizes tube life and mitigates future power reduction from loss of heat transfer capability.

• Conducted laboratory testing to confirm the technical feasibility of using chemical dispersants to manage steam generator deposits during the long-path recirculation cleanup process. Documented a generic qualification of a lead plant for an initial industry application and prepared a set of recommendations to guide development of an initial application plan.

• Evaluated the use of septa and precoat media in controlling feedwater iron in boiling water reactors. Results will provide input to the next revision of the EPRI Condensate Polishing Guidelines.
Continued collecting water chemistry data through EPRI’s Chemistry Monitoring and Assessment project to benchmark specific water chemistry regimes and optimize plant operation. As of December 2009, the pressurized water reactor (PWR) database contained 639 cycles of primary and secondary chemistry data from 67 U.S. and 80 non-U.S. PWR plants. The boiling water reactor (BWR) database includes data from all 35 U.S. and 11 non-U.S. BWR plants.

- Published first revision of the BWR Shutdown and Startup Chemistry Operating Experience and Sourcebook. This sourcebook summarizes BWR good practices for controlling corrosion product transport during shutdowns, particularly refueling outages, and for startup chemistry control to minimize intergranular stress corrosion cracking.
- Improved chemistry software by incorporating the PWR and BWR Shutdown Chemistry Calculator and Analyzer into ChemWorks™ Tools; and updated the MULTEQ Database with new and revised species.

**Current Year Activities**

Water Chemistry Program research and development for 2012 will focus on technology developments and assessments to continually improve guidance and tools for optimized chemistry control. Specific efforts will include the following:

- Begin revision of the boiling water reactor water chemistry guidelines and the pressurized water reactor primary water chemistry guidelines to incorporate industry initiatives and operating experience.
- Coordinate field implementation of a PWR primary reactor coolant system optimized (elevated) hydrogen program at a lead plant.
- Revise the pressurized water reactor zinc application guidelines by updating current industry experience, identifying best practices, developing a long-term zinc injection strategy, and providing guidance for operational decision-making.
- Begin development of water chemistry guidelines for new plant designs, based on assessments completed in 2010 and 2011 that evaluated planned operation against the current Water Chemistry Guidelines.
- Continue development of boiling water and pressurized water reactor monitoring and assessment tools to benchmark the industry and evaluate chemistry improvement opportunities.
- Revise the PWR Dispersant Application Sourcebook, adding information and recommendations related to application during steam generator wet layup and the long-path recirculation cleanup process during startup in addition to online application.
- Begin revision of the condensate polishing guidelines for boiling water and pressurized water reactors.

**Estimated 2012 Program Funding**

$4.5 million

**Program Manager**

Keith Fruzzetti, 650-855-2211, kfruzzet@epri.com
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<th>Project Number</th>
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<th>Description</th>
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<tbody>
<tr>
<td>P41.09.03.02a</td>
<td>SMART ChemWorksTM User Group - Maintenance and Support (supplemental)</td>
<td>This project provides support to the 24 current users of SMART ChemWorks, including two from the BWR fleet. Plant and corporate personnel have access to the SMART ChemWorks technology through a web interface, and can monitor plant chemistry on a continuous basis. An alert system is customized for each plant.</td>
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<tr>
<td>P41.09.03.03b</td>
<td>SMART ChemWorksTM User Group - New Installation (supplemental)</td>
<td>Installation of SMART ChemWorks requires a coordinated effort between EPRI engineers and plant team members. A one-time on-site meeting is required between team members to establish project scope and timelines to ensure a successful implementation plan. SMART ChemWorks requires that a data transfer tool be installed at the plant and that access be provided to the EPRI servers, after which plant personnel will have access to SMART ChemWorks through a web interface. Additional site-specific customizations are supported over the first 3 months as the model is developed and adjusted based on plant information.</td>
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<tr>
<td>P41.09.03.03d</td>
<td>ChemWorksTM User Group (supplemental)</td>
<td>The ChemWorks User Group provides several mechanisms for enhancing the ChemWorks software codes and their application at nuclear plants. Through industry forums, newsletters, annual meetings (U.S. and international), and webcast sessions, EPRI technical staff support utility application of the codes and gain insight into user experience that can lead to needed software modifications and improvements.</td>
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<tr>
<td>P41.09.03.04e</td>
<td>Chemistry Technical Strategy Group (supplemental)</td>
<td>The Chemistry Technical Strategy Group provides a forum for members to exchange ideas and lessons learned related to strategic management of BWR and PWR chemistry programs. The 3-year membership provides participants with all the benefits of an annual membership plus a full chemistry assessment once during the 3-year period. Participation on this basis is at a lower cost than having one assessment performed and subscribing to the Technical Strategy Group on an annual basis for 3 years.</td>
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</table>
| P41.09.03.05a | PWR Secondary Cycle pH Optimization (supplemental) | To help utilities minimize corrosion in the secondary cycle, EPRI has developed a process to evaluate plant pH optimization programs. EPRI experts help plant managers evaluate the status of their corrosion-product transport and local pHs throughout the secondary cycle. Evaluations include the following:  
- A mass balance of corrosion products around the secondary cycle to determine the corrosion source  
- Calculation of amine concentrations and local pH values at major locations in the secondary cycle using the EPRI Plant Chemistry Simulator  
- Calculation of feedwater iron concentrations  
- Estimation of polisher run length as a function of feedwater amine concentrations  
- Economic analysis comparing the use of different potential amines |
<p>| P41.09.03.06d | PWR Dispersant Application Support (supplemental) | This project provides plant-specific support for successful dispersant application, which can reduce steam generator fouling by as much as 50% based on plant trials and early results from application at Exelon. |</p>
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<tr>
<td>P41.09.03.07e</td>
<td>PWR Primary and Secondary Resins and Filters User Group (supplemental)</td>
<td>The PWR Primary and Secondary Resins and Filters User Group provides a forum for collecting industry best practices that can be used by member utilities to optimize operations with regard to demineralizer and filter performance.</td>
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<tr>
<td>P41.09.03.08f</td>
<td>PWR Primary Zinc Application User Group (supplemental)</td>
<td>The PWR Primary Zinc Application User Group provides members access to an annual meeting to update members on technology developments and to share experiences and best practices. As part of the Chemistry Monitoring Assessment Program, key parameters from utilities will be tracked and trended based on cycle performance in radiation exposure and zinc injection.</td>
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</table>
| P41.09.03.09a   | BWR Cycle Chemistry Evaluation (supplemental)            | This project will assist plant operators in evaluating their cycle chemistry and in developing a roadmap for chemistry improvements by performing the following:  
- Reviewing the technical basis for the site chemistry trending program using EPRI guidelines and other industry standards  
- Reviewing the effectiveness and completeness of chemistry-related corrective actions taken during previous cycles  
- Evaluating and trending chemistry results using EPRI-developed tools to document behaviors  
- Recommending site chemistry program improvements based on trends and observations  
- Conducting on-site walkdowns (as needed) of sample systems to review effectiveness  
- Assessing laboratory operations with respect to communication, equipment operation and maintenance activities, training, and implementation of industry lessons learned |
| P41.09.03.10b   | BWR Startup Hydrogen Injection Evaluation (supplemental)  | This project will assist plant operators in identifying preferred locations for early hydrogen injection during BWR startup as well as support initial planning efforts for possible plant modifications to accommodate the injection process. The evaluation team will perform the following:  
- Review plant drawings and documents for injection locations  
- Perform a plant walkdown to confirm preferred locations  
- Identify plant modifications required for injection tie-ins and services  
- Determine space availability should hydrogen gas cylinders be used  
- Document the results of the evaluation and provide plant-specific recommendations |
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| P41.09.03.11c  | BWR Feedwater Iron Optimization Support (supplemental) | This project supports efforts to improve the performance assessment accuracy of individual condensate filtration/demineralizer vessels for iron optimization. Support at a given plant includes the following:  
  • Temporary corrosion product sampler setup  
  • Baseline evaluation of current sampling/analysis program  
  • Consultation with station personnel for execution of site-specific sampling program  
  • Site-specific sampling program and sample analysis (lab analysis generally performed on-site by site personnel)  
  • Compilation and evaluation of results  
  • Site-specific recommendations regarding septa, precoated material and operating conditions to achieve feedwater iron control goals (electronic report included) |
| P41.09.03.12d  | BWR Condensate Filter User Group (supplemental) | Participation in the BWR Condensate Filter User Group provides access to an annual conference, electronic reports, newsletters, and industry alerts. Current issues include the following:  
  • Pleated septa experience and septa quality control  
  • Septa and precoated materials optimization  
  • Use of specialty resins for cobalt removal  
  • Equipment upgrades and related issues and resolutions  
  • Optimization of iron and soluble species removal  
  • Control of sulfate releases due to pleated septa age and attachment hardware failure  
  • Minimization of radwaste generation |
| P41.09.03.13f  | BWR Zinc User Group (supplemental) | Zinc injection has become a key technology for minimizing drywell dose rates under the highly reducing chemistry conditions established by hydrogen and noble metal water chemistry programs. While more zinc can be better for dose control, chemistry guidelines limit feedwater zinc concentrations to control the buildup of tenacious crud on the fuel cladding. The BWR Zinc User Group enables plants to accomplish the following:  
  • Share plant experiences and lessons learned with zinc application  
  • Review the BWR chemistry monitoring database for trends and updates  
  • Monitor zinc performance results based on available chemistry, radiation field, and fuel surveillance data  
  • Communicate issues and improvement plans for active and passive zinc injection systems  
  • Identify needed research involving zinc addition |
SMART ChemWorks™ User Group - Maintenance and Support (supplemental) (007452)

**Key Research Question**
Chemistry staffs in the nuclear power industry continue to shrink as a result of economic pressures and the aging work force. Highly skilled personnel spend too much time completing mundane but necessary tasks, while the backlog of important, but less time-sensitive obligations, continues to grow.

**Approach**
EPRI’S SMART ChemWorks™ is a real-time plant water chemistry monitoring and advisory system that aids chemistry staff by completing routine chemistry analysis, identifying early indications of adverse plant chemistry, and alerting personnel to emerging issues. Continued maintenance and support is required to ensure SMART ChemWorks incorporates the latest operating experience and is broadly applicable across the global nuclear industry.

**Impact**
SMART ChemWorks uses sophisticated mathematical models and pattern-recognition techniques to identify abnormal conditions. Once installed, plant managers can look forward to increased efficiency and better use of plant personnel, reduced risk of plant components damage, increased chemistry monitoring coverage and early detection of chemistry problems, improved control of chemical injection systems, reduced cost due to optimization of grab sample frequencies, and reduced “out-of-specification” time for instrumentation.

**How to Apply Results**
The SMART ChemWorks system relies on continuous chemistry monitoring (24 hours a day, 7 days a week) and real-time evaluation of plant chemistry conditions, accurate and prompt diagnosis of abnormal chemistry, and instantaneous alerting to adverse chemistry trends through an email/paging system and web page alerts. The output from SMART ChemWorks represents technical intelligence on which plant chemists can take action as appropriate.

SMART ChemWorks™ User Group - New Installation (supplemental)

**Key Research Question**
Chemistry staffs in the nuclear power industry continue to shrink as a result of economic pressures and the aging work force. Highly skilled personnel spend too much time completing mundane but necessary tasks, while the backlog of important, but less time-sensitive obligations, continues to grow.

**Approach**
EPRI’S SMART ChemWorks™ is a real-time plant water chemistry monitoring and advisory system that aids chemistry staff by completing routine chemistry analysis, identifying early indications of adverse plant chemistry, and alerting personnel to emerging issues. Installation of SMART ChemWorks requires a coordinated effort between EPRI engineers and plant team members. A one time on-site meeting is required between team members to establish project scope and timelines to ensure a successful implementation plan.

**Impact**
SMART ChemWorks uses sophisticated mathematical models and pattern-recognition techniques to identify abnormal conditions. Once installed, plant managers can look forward to increased efficiency and better use of plant personnel, reduced risk of plant components damage, increased chemistry monitoring coverage and early detection of chemistry problems, improved control of chemical injection systems, reduced cost due to optimization of grab sample frequencies, and reduced “out-of-specification” time for instrumentation.
How to Apply Results

The SMART ChemWorks system relies on continuous chemistry monitoring (24 hours a day, 7 days a week) and real-time evaluation of plant chemistry conditions, accurate and prompt diagnosis of abnormal chemistry, and instantaneous alerting to adverse chemistry trends through an email/paging system and web page alerts. The output from SMART ChemWorks represents technical intelligence on which plant chemists can take action as appropriate.

ChemWorks™ User Group (supplemental) (006521)

Key Research Question

Economic pressures, work demand and reduced staffing require chemists to spend more time in the field and less time evaluating changes in the chemistry programs. ChemWorks™ provides users with a simple set of tools to quickly evaluate plant chemistry controls.

Approach

The ChemWorks User Group provides several mechanisms for enhancing the ChemWorks software codes and their application at nuclear plants. Through industry forums, newsletters, annual meetings (U.S. and international), and webcast sessions, EPRI technical staff gain insight into user experience that can lead to needed software modifications and improvements.

Impact

ChemWorks uses sophisticated mathematical models to aid plant chemists in developing optimal chemistry programs and applying appropriate chemistry controls that support long-term equipment reliability. Users Group members provide input into continued software improvements that reflect industry needs and experience.

How to Apply Results

User Group members receive direct support via meetings and product development as well as individual training on ChemWorks™ codes.

Chemistry Technical Strategy Group (supplemental)

Key Research Question

The Chemistry Technical Strategy Group provides a forum for discussing technical issues regarding the strategic management of BWR and PWR chemistry programs. Emerging chemical issues challenge plant staff in both the day-to-day and long-term management of chemistry programs. This group enables members to exchange ideas and information related to emerging issues as well as lessons learned.

The Chemistry Technical Strategy Group is available in 3-year and 1-year membership options. The 3-year membership includes 1 full cycle chemistry assessment.

Approach

The Chemistry Technical Strategy Group, available as a 3-year membership, enables plant chemists from BWRs and PWRs to share best practices and discuss chemistry challenges. Meetings will include general sessions to address common chemistry issues and break-out sessions to address issues specific to BWRs and PWRs.

In addition to the member forum for sharing lessons learned, participants are eligible for annual technical consulting and a focused assessment during the 3-year membership period. The chemistry assessment entails an expert review of a plant’s chemistry program and recommendations on how EPRI technology can assist in addressing plant-specific issues and improving chemistry performance.
Impact
Participation in the Chemistry Technical Strategy Group keeps members abreast of emerging issues in the rapidly changing climate surrounding chemistry issues and provides members with a forum for technical exchange. On-site consulting time provides expert support for specific plant or corporate project requests focused on long-term strategic planning.

How to Apply Results
Participation in periodic webcasts and meetings keeps members abreast of emerging issues. Annual on-site consultation time and the focused chemistry assessment are used to ensure EPRI guidance is applied to emerging and critical plant-specific issues. The annual consultation time is used to address more narrowly focused issues, while the full assessment provides a broader programmatic perspective. Both venues provide plant-specific recommendations to maximize plant benefits.

PWR Secondary Cycle pH Optimization (supplemental) (064149)

Key Research Question
Materials corrosion in the condensate, feedwater, and drain systems of pressurized water reactors (PWRs) generates a significant amount of corrosion products in the secondary cycle. Generally, these corrosion products are transported into steam generators (SGs) and deposited on tubing surfaces, tubesheets, and tube support plates. These corrosion products can act as sites for ionic impurity concentration in restricted areas, leading to corrosion of steam-generator tubing.

Approach
This project will develop a plant-specific corrosion-products mass balance file based on current plant equipment. The mass balance results are evaluated to assess how changes in the type and concentration of amines could optimize secondary cycle pH.

Impact
Local pH strongly affects corrosion of several different types, including intergranular attack and stress corrosion cracking. The right choice of amines and proper operation of a pH control additive will reduce SG fouling and deposit consideration. Secondary-cycle pH optimization aids in the selection of optimum amines for the plant, thus minimizing corrosion product transfer.

How to Apply Results
Members receive a detailed report discussing the status of corrosion-product transport and local pHs in the secondary cycle, along with recommendations and supporting documentation for optimum amine selection. Application of these results will support an optimized feedwater iron control.

PWR Dispersant Application Support (supplemental) (061414)

Key Research Question
Steam generator deposits (fouling) can inhibit heat transfer, lead to thermal-hydraulic instabilities through blockage of tube supports, and create occluded regions where corrosive species can concentrate along tubes and in tube-to-tube support plate crevices. Steam generator performance is compromised not only by formation of an insulating scale, but by the removal of tubes from service due to corrosion.

Dispersant application is a very promising technology for significantly reducing steam generator fouling. A number of utilities are pursuing dispersant applications using the PWR Dispersant Application Sourcebook (1015020) and additional plant-specific support as provided through this project. EPRI also can assist in evaluating newer dispersant application technologies. For example, dispersants can be used for increasing
cleanup of corrosion products during steam generator wet layup or during long-path recirculation cleanup of the condensate/feedwater piping prior to power operation.

**Approach**

This EPRI project will support assessment and application of dispersant for steam generator fouling mitigation. Specific work will be determined in collaboration with the funding utilities, depending on need and plant-specific concerns. Assessments could involve the following:

- Plant-specific materials qualification assessment
- Chemistry operation and monitoring with dispersant injection (application plan)
- Evaluation of steam generator thermal performance, including a baseline evaluation prior to dispersant injection and customization of a thermal performance tracking spreadsheet
- Preparation of materials needed to support a 10CFR50.59 evaluation

**Impact**

Successful on-line application of dispersant could reduce steam generator fouling by as much as 50% based on results from previous plant trials. Other applications during steam generator wet layup and startup could provide additional benefits.

**How to Apply Results**

The products from this project are assessments, site-specific reports, and/or recommendations in support of application at a lead pressurized water reactor (PWR) unit. EPRI works with each funding utility to identify and deliver what is needed for successful application, within funding constraints.

**PWR Primary and Secondary Resins and Filters User Group (supplemental) (063963)**

**Key Research Question**

To minimize ionic and particulate impurity transport in the reactor coolant and the steam generators, PWR plants employ a wide variety of chemical and volume control systems, condensate polishers, and steam generator blowdown demineralizer systems and use different strategies to operate these systems. The PWR Primary and Secondary Resins and Filters User Group provides a forum for sharing industry experience that can improve and accelerate plant activities to reduce impurity transport.

**Approach**

The User Group will track operating experience and perform focused studies on specific industry issues. Technology reviews and comparisons of plant practices, for example, will help plants improve reactor coolant system cleanup, reduce iron transport to the steam generators, and reduce low-level waste generation. Review and benchmarking activities will be performed through annual meetings, with products defined by members. The PWR Primary and Secondary Resins and Filters User Group will function in a manner similar to the BWR Condensate Filter User Group, which was formed in the late 1990s to address problems and optimization issues with condensate filters.

**Impact**

This group will identify and improve the application of demineralizers, filters, and membrane technologies applied in PWRs by assisting in the evaluation of filter and ion exchange performance and by sharing of information concerning filter design, novel resin use, and other general operating experience.

**How to Apply Results**

Application of the practices identified as optimal will be performed at member utilities on an as-needed basis. A key product target will be development of a demineralizer and filter sourcebook, from which users can reference industry best practices.
PWR Primary Zinc Application User Group (supplemental) (061425)

Key Research Question
Many EPRI reports have been published over the years regarding the effectiveness of zinc addition for primary water stress corrosion cracking mitigation (for both initiation and crack growth rate), including the development of PWR Zinc Application Guidelines in 2006. However, there remains a strong need for plant personnel to exchange information first-hand and provide focused input on future research activities.

Approach
At each user group meeting, members provide an update on their plant or utility's zinc injection program status. These updates address all aspects of a zinc injection program, including planning, implementation, scheduling, and long-term strategy. The user group members also receive updates related to pressurized water reactor (PWR) reactor coolant system zinc addition.

Impact
The Zinc User Group provides a forum for members to benchmark new and existing zinc injection programs throughout the industry. Sharing of lessons learned and annual updates related to EPRI research programs associated with zinc addition will provide utilities with valuable information to guide planning and implementation.

How to Apply Results
The plant experiences and challenges shared through the Zinc User Group provide learning opportunities for the entire industry. Plant personnel are able to bring these lessons learned back to their plants for implementation for further analysis.

BWR Cycle Chemistry Evaluation (supplemental)

Key Research Question
Plant chemistry programs are instrumental in maintaining nuclear plant reliability and availability. In-depth technical reviews of a boiling water reactor's (BWR's) cycle chemistry can provide specific recommendations aimed at optimizing chemistry control, enhancing plant operations, mitigating stress corrosion cracking, ensuring fuel reliability, and reducing radiation exposure and radioactive waste generation.

Approach
This project will assist plant operators in optimizing BWR chemistry. Plant-specific evaluations of the most recent operating cycle will be evaluated and recommendations will be made to support enhanced plant operation.

Impact
- Improved plant operation and cycle chemistry control
- Reduced costs for chemicals, additives, and other consumables
- Reduced stress corrosion cracking of susceptible components
- Lower radiation dose and radioactive waste
- Improved fuel performance

How to Apply Results
By applying the detailed report recommendations, plant operators can maximize plant performance and aid in extending plant life. Recommendations may include optimization of condensate treatment and reactor water cleanup systems, additive chemistries (such as zinc addition, hydrogen addition, and/or noble metal addition), and improvements in chemistry sampling and analysis programs.
**BWR Startup Hydrogen Injection Evaluation (supplemental)**

**Key Research Question**
All U.S. boiling water reactors (BWRs) are currently injecting hydrogen to mitigate stress corrosion cracking of susceptible components. However, hydrogen injection is typically not injected until the plant is at 5% power or more. Earlier injection of hydrogen, specifically at plant startup until typical feedwater hydrogen injection can be initiated, could provide additional mitigation value. Utilities interested in this technology may need support in implementing this technology.

**Approach**
This project will assist plant operators in identifying preferred locations for early hydrogen injection during BWR startup as well as support initial planning efforts for possible plant modifications to accommodate the injection process.

**Impact**
- Early identification of physical plant constraints
- Shorter lead times for system implementation
- Improved project scoping and accuracy
- Tighter budget and schedule control

**How to Apply Results**
Plant-specific recommendations as documented in the final report will detail how early hydrogen injection can be optimized at the plant.

**BWR Feedwater Iron Optimization Support (supplemental) (062736)**

**Key Research Question**
The *BWR Water Chemistry Guidelines* recommend feedwater iron concentration in the range of 0.1-1.0 ppb for plants operating with zinc addition and reducing chemistry conditions (hydrogen water chemistry as well as noble metal application technologies). Operation in the range of 0.1-0.5 ppb is further encouraged to reduce the amount of zinc needed for dose rate control purposes. While many plants have been able to achieve these conditions, plants with non-optimized condensate filtration/demineralizer systems may need additional support to reduce feedwater iron inputs to these recommended levels.

**Approach**
This project supports the optimization of feedwater iron by analyzing current operation and performance and providing recommendations to optimize future performance of the condensate filtration demineralizer system.

**Impact**
The optimization of feedwater iron input results in enhanced plant operation:
- Reduced radwaste generation and exposure
- Improved fuel performance and reliability
- Optimized stress corrosion cracking mitigation technologies (such as hydrogen addition and noble metal injection)

**How to Apply Results**
This project provides direct consultations with plant staff and a final electronic report detailing the project work and recommendations. Implementation of the report recommendations regarding precoat usage and dosage on septa will be detailed. Application of these results will support optimized feedwater iron control.
**BWR Condensate Filter User Group (supplemental) (006388)**

**Key Research Question**

While nuclear industry experience with condensate filtration is extensive, the variety of septa types, precoat materials, vessel designs, backwash, and precoating methods present application challenges. Open dialogue among users to share experiences can drive excellence in performance, especially with the ever-increasing emphasis on water chemistry limits and impacts on fuel performance, stress corrosion cracking mitigation, and radwaste and exposure reduction.

**Approach**

The BWR Condensate Filter User Group supports optimization of water chemistry filtration technologies to control important chemistry parameters. Through annual User Group conferences, electronic reports, newsletters, and industry alerts, members gain access to industry experience that can be tailored to individual plant applications. A database of operational and technical information is maintained to address condensate filter system challenges.

**Impact**

This User Group has been successfully supporting the nuclear industry for more than 10 years. The database of operational and technical information provides extensive insight into the understanding of condensate filter system challenges. Lessons learned and implemented from the User Group results in reduced radwaste and worker exposure, optimized fuel performance, and enhanced overall plant operation.

**How to Apply Results**

Members of the BWR Condensate Filter User Group apply the experience of other member's situations to their own utility. Special studies also are made available on a plant-specific basis and shared with the membership group.

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**BWR Zinc User Group (supplemental)**

**Key Research Question**

Many Electric Power Research Institute (EPRI) reports have been published over the years regarding plant experience with zinc injection on drywell shutdown radiation dose rates and laboratory investigations on zinc effectiveness for intergranular stress corrosion cracking (IGSCC) mitigation for sensitized Alloy 600, 304 stainless steel, and Alloy 182 weld metal. However, given the need to balance the chemistry and radiation benefits of zinc with fuel concerns regarding tenacious crud deposits and the potential effects of crud/oxide spallation, there remains a strong need for plant personnel to exchange information first-hand and provide focused input on future research activities. These activities can be supported through a BWR Zinc User Group.

**Approach**

The BWR Zinc User Group will enable participants to update peers on plant/utility zinc injection programs. Updates will address all aspects of the zinc program, including planning, implementation, scheduling, and long-term strategy. User Group members will receive updates related to radiation field control, reactor water and feedwater zinc data trends, reactor water Co-60(s)/Zn(s) ratio control, Co-60 trends, and effectiveness of Zn injection following noble metal applications and reactor recirculation piping chemical decontaminations.

**Impact**

The BWR Zinc Users Group will provide a forum for utilities to benchmark zinc injection programs throughout the industry. Sharing of lessons learned and annual updates related to EPRI research programs associated with zinc addition will provide utilities with valuable information to guide planning and implementation.
How to Apply Results

The EPRI BWR Zinc User Group will provide members with access to industry data relevant to zinc injection, data correlations, an annual User Group meeting to share and benchmark plant experiences related to zinc injection, and discussion of EPRI zinc-related projects and work prioritization.
Long Term Operations (QA)

Program Overview

Program Description
High capacity factors and low operating costs make nuclear power plants some of the most economical power generators available. Even when major plant components must be upgraded to extend operating life, these plants often represent a cost-effective, low-carbon asset. The decision to extend nuclear plant life involves a host of inter-related technical, economic, regulatory, and public policy issues. Unknown or uncertain technical inputs impact the decision-making process both directly and indirectly: directly, through design and operational contingencies; and indirectly, through impacts on regulatory actions and public policy.

Recognizing the many technical challenges confronting extended nuclear plant operations, the Long-Term Operations Program is conducting an array of research and development (R&D) activities to ensure the public, the nuclear plant owners, regulatory agencies, and all interested stakeholders have the information needed to make sound decisions regarding the ability of a nuclear plant to sustain safe, reliability, economic operations.

Research Value
The Long-Term Operations Program will develop that technical information base on which to base decisions regarding extended nuclear plant life. Research results will not only inform those plant owners considering life extension past 40, 50, or 60 years, but also those with relatively younger plants considering the long-term impacts of aging. Participants gain access to technical solutions and information in the following ways:

- Identifying and overcoming key technical barriers
- Investigating cost-effective modernization opportunities
- Informing potential regulatory issues
- Capitalizing on substantial government, participant, and global research and development investments

Approach
The factors driving interest in long-term nuclear plant operations correspond to specific challenges where technical insight can effectively inform decision-making. Although these challenges touch different aspects related to long-term operations—from the physical condition of the plant to the allocation of capital budgets for plant refurbishment—they all require focused research and development to ensure technical constraints and opportunities are fully understood. The Long-Term Operations Program is designed to address these constraints and opportunities, encompassing activities facing extended operation through 30 or 40 years, all the way up through 60 or more years. The program accomplishes its objectives through an integrated strategy that involves research defined by the Electric Power Research Institute (EPRI) and its participants, collaboration on complementary research activities through the Department of Energy's Light Water Reactor Sustainability Program, and engagement with other key stakeholders such as the Materials Aging Institute. This strategic integration and coordination ensures a technical basis will be in place to inform life extension decisions in the 2014-2019 timeframe.

The activities conducted through the Long-Term Operations Project are identified and prioritized in association with nuclear plant owners, regulators, and other key stakeholders. The project also builds on the technical experience and expertise accumulated through EPRI leadership in the U.S. license renewal effort in the 1990s and early 2000s.

Research products satisfy one or more of the following criteria: 1) modernization and enhancement opportunities for existing plants that offer significant cost and/or performance benefits; 2) technical bases for evaluating continued operation of systems or components likely to be subject to aging and considerable public and/or regulatory scrutiny; and 3) enhanced analytical capabilities that enable defensible technical assessments without long-term testing.
Research activities for 2012 are focused in seven technical areas:

- Primary system materials aging
- Concrete and containment aging
- Advanced nuclear fuel technology
- Safety analysis methods
- Instrumentation and control and information technology
- Life-cycle management
- Cable aging

Pilot demonstrations will play an important role in characterizing issues impacting long-term operations and, subsequently, in demonstrating mitigating actions and new technology capabilities. For example, EPRI, the Department of Energy (DOE), and Constellation Energy have established a multi-year collaborative effort to investigate aging concerns at the Ginna and Nine Mile Point nuclear plants, which are both more than 40 years old. Initial assessments will include a comprehensive concrete containment examination and an incremental reactor internals inspection for aging issues.

Accomplishments

EPRI’s Long-Term Operations Project has grown into a large research effort with broad collaboration across multiple countries and entities. Significant research results will be emerging over the next few years. Key results from initial research activities include the following:

- Identified and prioritized long-term operations issues in a Long-Term Operation (LTO) Issue Tracking Table. This table is the basis for collaborative R&D programs at the Department of Energy (DOE) and EPRI.
- Compiled a report documenting concrete structures at U.S. nuclear power plants that can be used to identify and coordinate research targeting concrete aging.
- Issued a report documenting good practices, barriers, and gaps related to the use of information technology for driving improvements in equipment reliability.
- Initiated research to develop and validate an integrated framework and advanced tools that will enable accurate characterization and visualization of nuclear power plant safety margins. Such tools are needed to account for plant operational changes that can affect original design margins over time, such as power uprates.
- Developed a project plan defining flexible functional requirements for control room and underlying instrumentation and information technology infrastructure, architecture, and associated capabilities that will support plants throughout their extended operating life.
- Developed functional requirements for the Phoenix software, an advanced risk code that would enable analysis of all modes and hazards, and an integrated risk profile of the entire plant.

Current Year Activities

Long-Term Operations research for 2012 will focus on the following:

- Application of Concrete Structures Reference Manual and Degradation Database
- Characterization, modeling, and mitigation of intergranular stress corrosion cracking in nickel alloys and irradiation-assisted stress corrosion cracking in stainless steel
- Enhanced safety analysis and tools development for safety margin characterization
- Enhanced centralized online monitoring methods and pilot studies for critical systems, structures, and components
- Methods and database enhancements for life-cycle management of key components, refurbishments, and uprates

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977.
**Estimated 2012 Program Funding**

$6.0M

**Program Manager**

John Gaertner, 704-595-2666, jgaertner@epri.com

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**Summary of Projects**

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**Primary System Materials Aging (base) (QA)**

**Key Research Question**

Degradation of metals in the primary systems of nuclear power plants is a focus of aging management activities at operating nuclear plants. Failures or unexpected degradations significantly affect safety, plant availability, and cost of operation; and their impact will only increase with long-term operation. Better understanding of crack initiation and propagation processes, improved predictive models, and effective countermeasures against embrittlement and stress corrosion cracking are imperative. The degradation models enable prediction of remaining-useful-life and the development and testing of mitigation methods.

**Approach**

This project plan is comprised of 5 projects that address the problems considered of highest priority for long-term operations:

- Extension of Materials Degradation Matrix (MDM) and Issues Management Tables (IMT) to Include Failure Mechanisms to 80 Years.
- Irradiation-Assisted Stress Corrosion Cracking (IASCC): Identifying Mechanisms and Mitigation Strategies for IASCC of Austenitic Steels in LWR Core Components
- Reactor Pressure Vessel Embrittlement
- Advanced Welding Methods for Irradiated Materials
Impact
Results from these projects can serve numerous industry objectives ranging from identifying inspection needs and responding to emergent operating experience issues in the near term to identifying new alloys for future plant applications.

How to Apply Results
The specific products for LTO will be compilations of these research results into useful tools and methods such as automated knowledge bases, predictive algorithms or models, modeling and simulation tools, implementable inspection methods, and aging management guidelines, including repair and replacement guidance.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Concrete and Containment Aging (base) (QA)

Key Research Question
Aging of civil infrastructure in commercial nuclear power plants is a potential “show-stopper” in lieu of long term operation. There are a variety of kinetic processes that can lead to the degradation of civil structures—and these may be accelerated by operating environments specific to nuclear plants (for example, spent fuel pool leakage). It is important that the industry understand the impact of accelerated aging of civil infrastructure, particularly for LTO, as individual utilities will be required to provide both sound technical and economic justifications to continue operation to 80 or 100 years.

Approach
The goal of this project is to examine various degradation phenomena being experienced in operating plants. The project will initially compile an Aging Reference Manual that clearly defines the physics of kinetic degradation processes and discusses the corresponding operational issues. The manual will contain a framework for identifying at-risk structures and applicable degradation mechanisms. Individual research projects, aimed at further understanding of those degradation mechanisms and structures identified as “at-risk”, will be commenced. The results of the individual studies will be merged into an Aging Management Toolbox Platform as an open-ended tool for operators to assess severity of damage and explore repair or mitigation options.

Impact
It is anticipated that the project will developed a valuable tool for utilities to manage aging concrete structures. The value of the tool will increase as more degradation mechanisms and structure modules are added in out years. The product will be left open-ended to allow expansion as new issues emerge.

How to Apply Results
Pilot plant investigations for LTO issues are expected to yield one or more industry examination guidelines for concrete aging assessment.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.
**Advances in Nuclear Fuel Technology (base) (QA)**

**Key Research Question**

The overall objective of this work is to assess the performance of silicon carbide fuel cladding, a material that shows promise for substantial power uprate potential (perhaps 30-40% higher power) and may eliminate consequences of design basis accidents (the ability of the clad to withstand temperatures higher than the current 2200°F peak cladding temperature during a loss-of-coolant accident [LOCA], which could revolutionize the safety margins and emergency core cooling systems [ECCS] requirements).

**Approach**

The LTO project will address two specific concerns with SiC cladding:
- Establish a viable fuel rod thermal-mechanical design. All fuel rod designs require a fuel performance code to optimize the design (for example, fuel and clad dimensions, enrichment, and rod pressure), but advanced codes such as EPRI’s FALCON did not previously have the necessary materials models to assess SiC cladding.
- Develop a reliable bond between the tube and the end cap. This is challenging because the common approaches (for example, brazing with a glassy material) will not hold up reliably under LWR conditions.

**Impact**

The key benefits are improved fuel performance, including power uprate capability, higher burnup levels, and greater thermal margins during transient or accident conditions. This advanced fuel concept also will likely become a significant focus of the DOE Light Water Reactor Sustainability (LWRS) Program, so a key aspect of this project in LTO is its ability to inform (and thereby focus and accelerate) the larger DOE effort.

**How to Apply Results**

The objective of this effort is to have fuel rod segments in a test reactor in 5 years and full-length rods in a commercial LWR in 10 years. Successful completion of these efforts is expected to lead to commercial offerings from fuel suppliers.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

**Safety Analysis Methods (base)**

**Key Research Question**

To achieve long-term operation (LTO), it will be imperative that nuclear plants maintain high levels of safety and economic performance. Thus, nuclear power plants (NPPs) will have a continuing need to undergo design and operational changes as well as manage aging degradation while simultaneously preventing the occurrence of safety significant events and analytically demonstrating continued compliance with license safety margins.

**Approach**

First, as plants age, it is anticipated that new challenges to nuclear plant safety will emerge. These challenges could be due to any number of causes, such as a change in regulatory policy or the occurrence of an event at one or more operational plants.

Second, as new technologies and capabilities become available, it will be desirable to take advantage of these opportunities to enhance plant technical and economic performance. Examples could include performing extended power uprates or implementation of new technologies or materials.
In each situation, a comprehensive and integrated assessment of the impact on nuclear safety will be required to support effective and efficient decision-making. This project will develop both the analysis framework—risk-informed safety margin characterization (RISMC)—and, as appropriate, calculation tools to support safety analyses. This effort is tightly coordinated with DOE efforts on advanced analysis tools.

**Impact**

The major objectives of the Risk-informed Safety Margin Characterization (RISMC) research activities are as follows.

- Achieve significant progress toward a consensus approach accepted by nuclear plant operators, regulatory authorities, and other stakeholders for risk-informed safety margin assessments.
- Through collaboration with the DoE LWRS Program’s R7 development effort, achieve significant progress on developing advanced / enhanced deterministic safety analysis (DSA) capabilities, computational engines, results visualization, and validation.
- Support the development of the broad application of an integrated probabilistic risk assessment (PRA) tool (Phoenix) with advanced computational methods, full scope PRA aggregation capabilities, results visualization, and connectivity to plant information for configuration risk management.
- Achieve significant progress towards implementation of an integrated RISMC capability including interface of PRA and DSA codes with provisions to achieve broad connectivity to plant information and simulation capability.

Application of these technical results is expected to both improve accuracy and reduce efforts for plant safety analyses and to assist utilities in maintaining required safety margins for extended plant operations.

**How to Apply Results**

This research project will develop and validate an integrated framework and advanced tools for risk-informed assessments that enable accurate characterization and visualization of plant safety margins. One outcome of this research effort will be to integrate the results obtained from the Phoenix software, which is being developed to provide advanced probabilistic risk analysis (PRA) and configuration risk management (CRM) capabilities. Software tools, application guidance, and pilot demonstration efforts will be used to implement research results.

**I&C and Information Technology (IT) (base)**

**Key Research Question**

In the broad context of technology shift from analog to digital instrumentation and control (I&C), nuclear plants are facing increased maintenance costs and replacement supply issues with maintaining their original analog-based systems. This issue will continue to grow over time. This project will develop cost-effective strategies and implementation guidance to support the transition to digital technology.

**Approach**

This EPRI project will focus on two key areas:

- EPRI will participate on the LWRS Working Group on Advanced I&C and Human Systems Interaction (HSI). This working group includes utility representatives from Exelon, Entergy, Duke, Wolf Creek, and the STARS Alliance. Through the working group, the DOE LWRS program is sponsoring pilot studies of advanced applications of I&C and other information technology projects at individual utilities. LWRS also is developing an Advanced I&C User Facility to support these applications and to perform related R&D at INL. EPRI will participate in these activities on behalf of the LTO project membership.
- EPRI will develop a repository of advanced I&C, HSI, and other information technology requirements and good practices from the pilot studies and from other industry activities. The purpose of this repository is to have a living resource for utilities to review the state-of-the-art and good practices in the industry related to I&C enhancement projects.
Impact

Effective and licensable implementation of digital I&C technology can reduce current maintenance costs associated with analog systems, improve operator interfaces and resulting decision-making, and provide enhanced data sources for identifying potential operating issues.

How to Apply Results

The vision for this project is to develop and maintain a living repository of advanced I&C requirements and attributes for upgrades and replacements of I&C systems, human system interface with information systems, and other information technology in support of plant processes. These requirements and other attributes will be developed from utility applications done in collaboration with the DOE LWRS Program, other applications initiated by individual utilities, and demonstrations of technology at the DOE LWRS I&C test facility. It is expected that this repository will grow in size and sophistication throughout the next 8 years of the project, and it will evolve as technology advances.

Life Cycle Management (base)

Key Research Question

To achieve long-term operation (LTO), nuclear plant operators must maintain and/or enhance high levels of safety, reliability, and economic performance as are enjoyed today. Plant operators will need to be equipped with sound scientific and consistent technical knowledge bases to provide them the optimum information in support of their plant asset extended operation decisions of 60 years and beyond. Refurbishment and/or replacement of large capital assets not normally considered during the original licensed life may now come into play. This project will identify those large capital assets. This project will develop a standard knowledge base for selected large capital assets, supported by science, as well as operating experience and methods that provide consistency of information that plant operators can utilize in support of their long range plant and fleet strategic technical and business decision models.

Approach

Two principal deliverables will result from this project:

- An asset database that will define the large capital assets needed to support an integrated long-range plan, with required fields and guidance for the use of the database
- A guidance document that describes the integrated methodology and attendant bases for the timing, cost, and levelization of large capital assets for the remainder of plant operation

The guidance document and database will be developed concurrently to ensure that the data are appropriately structured to support the method. As appropriate, pilot applications of the database information per the guidance document process will be used to demonstrate and confirm the technical approach.

Impact

The guidance from this project will provide the capability for simulation and sensitivity analysis for the input variables with ability to forecast end-of-plant life, expected capital funding requirements, and optimization of input variables. The intent of this guidance is to provide plant operators with the best available information to support their decision for the extended operation of their facilities.

How to Apply Results

The database in conjunction with the guidance document is expected to allow a wide range of capital/maintenance investment assessments using utility-specific costing models and tools.
Cable Aging (base) (QA)

Key Research Question
Operating plant experience has identified the potential for cable failures as a result of aging and environmental factors. The data generated from operations are not sufficient to establish predictive capabilities or to define improved nondestructive evaluation (NDE) techniques for detecting aging effects that lead to failure. A reproducible, accelerated, cable aging process could be used to address these issues for cable life management.

Approach
This project seeks to develop a process for accelerated aging of pink ethylene propylene rubber cable insulation under wet, energized conditions. Based on success in development work, the project will perform accelerated aging of multiple samples of pink ethylene propylene rubber insulation to determine point of first detectible level of degradation; continue aging of additional specimens to establish aging model/curve of aging time versus test result; and continue testing through failure of a significant portion of the sample population.

Impact
Successful development of a reliable process for cable aging will allow follow-on development of better NDE techniques for detection of cable degradation damage and development of better remaining life prediction approaches.

How to Apply Results
Development of a successful cable aging process is a necessary first step in a robust life management process that will allow utilities to avoid in-service failures and to better plan and execute cable replacement efforts as required.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.