Advanced Nuclear Technology

Program Overview

Program Description

Renewed interest in the deployment of new nuclear power plants has introduced a host of technological, economic, and regulatory challenges. The Electric Power Research Institute's (EPRI's) near-term research in advanced nuclear technology focuses on the technologies and tools to enhance deployment of new nuclear plants, including welding best practices, risk-informed inspections, equipment reliability lessons learned, materials management, seismic modeling, and advanced cooling technologies to reduce water consumption. Longer-term research focuses on issues potentially limiting nuclear growth, including integrated spent-fuel management and the development of next generation nuclear plants.

Industry Needs and Issues Addressed

- New nuclear plant designs that reflect technology transfer from ongoing research and existing plant experience to achieve high capacity, reliability, and availability factors
- Tools that support planning and decision analysis related to new nuclear plant deployment
- Recognition and technical evaluation of emerging issues with significant impacts on nuclear plants, such as water availability
- Sustained availability of a skilled, productive, and innovative nuclear work force
- Evaluation of various future nuclear-related business models, including hydrogen production
- Development and evaluation of nuclear fuel cycles that can address high-level waste concerns and increase plant performance

Impact

- Leadership in deploying next-generation light water reactor designs that fully incorporate current plant operating and research and development (R&D) experience
- Competitive new plant and system designs for near-term deployment
- Planning tools to inform new plant project decisions related to scheduling, contracting, licensing, and defining resource requirements
- Highly leveraged research to support resolution of high-temperature gas reactor technology gaps
- Forward-looking technical and economic evaluations of nuclear energy cycles to assist in business model planning

Key Accomplishments

- Program restructuring with a strong industry advisory committee and a balanced focus on near-term advanced nuclear plant deployment and long-term nuclear sustainability (next-generation technologies and integrated waste management)
- Completed the Materials Management Matrix (MMM) for the evolutionary simplified boiling water reactor (ESBWR) nuclear plant design, providing materials-related input for technology design improvements (EPRI Report 1016334)
- Published the *New Plant Deployment Program Model*, which enables users to systematically analyze various licensing, technical, and plant deployment issues, thereby improving the decisionmaking process (EPRI Report 1015113)
- Completed a report on the effects of high-frequency seismic motions on nuclear plant structures, systems, and components (EPRI Report 1015108)
- Published *Utilities Requirements Document Technology Transfer Update - Rev 9* (EPRI Report 1015106)

Current Year Objectives

- Develop Revision 10 to the *Utilities Requirements* document
- Develop Materials Management Matrices for additional advanced plant designs (AP-1000 and EPR)
- Initiate research projects on Central and Eastern United States (CEUS) Seismic Source Characterization, New Plant Common Commodity Specifications, Practical Welding Best Practices, Equipment Reliability Guidelines for New Nuclear Plants, and risk-informed inspection methodologies for new plant design and operation
- Evaluate the economics of alternative cooling technologies for nuclear power plants
- Analyze integrated waste management options and high-temperature gas reactor research needs with the Next Generation Nuclear Plants (NGNP) Alliance and the Global Nuclear Energy Partnership (GNEP) Program

Industry Involvement

- Estimated 2009 funding: $6.0

Program Technical Lead

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Summary of Projects

Project Number	Project Title	Value
	New Nuclear Plant Deployment Program Model (NPDPM)	
	New Nuclear Plant Materials	Materials Management Matrices will be produced for the ESBWR (completed), AP1000, and EPR. They will list various critical information for each of the components in the nuclear steam supply system (NSSS) (American Society of Mechanical Engineers [ASME] Class 1 equivalent) and become living documents for managing life-cycle material issues.
	Technology Transfer to New Nuclear Plants and URD Update	The primary objective of the Utilities Requirements Document Update project is to transfer recent results from EPRI R&D, as well as EPRI and industry-collected operating experience to new plant designs. The information transferred to the new plant designs will be documented in Utility Requirements Documents (URD) updates beyond the current Revision 9.
	New Nuclear Plant Equipment Reliability	EPRI has a substantial portfolio of Equipment Reliability (ER) knowledge that has been effectively deployed across much of the current industry. This project will work with nuclear plants to effectively deploy existing ER tools in new plant designs to increase their potential for meeting business goals.

Project Number	Project Title	Value
	New Nuclear Plant Seismic Issues	EPRI is updating a seismic hazard model for the Central and Eastern United States (CEUS) that will facilitate new plant siting and respond to regulatory concerns. An updated generic CEUS seismic hazard model will benefit several industry participants: a) nuclear power plant owners and developers that have submitted an early site permit (ESP) or combined operating license application (COLA) for Nuclear Regulatory Commission (NRC) review in 2007 (or 2008) or will submit a COLA for a second unit in or after 2009; b) nuclear power plant owners and developers that will submit an ESP or COLA for NRC review in or after 2009; and c) operating nuclear power plant owners that must respond to issues resulting from NRC Generic Issue 199 (GI-199).
	New Nuclear Plant Equipment	
	New Nuclear Plant NDE	Based on previous experience with the successful implementation of EPRI's risk-informed inservice inspection (ISI) methodology to a variety of nuclear plant designs, EPRI will test and refine the methodology for advanced plants. The goal would be to develop a single pre-service inspection (PSI)/ISI program for each design (i.e. not site specific) or define any issues and provide guidance where they may be site-specific requirements. Second, EPRI will work with ASME Sections III (construction) and XI (inspection) to initiate and provide the technical basis for the necessary actions in Section III to allow acceptance of benign welding flaws by structural analysis. Finally, this project will establish and operate the ultrasonic (UT) examination qualification programs that will be necessary to assure accurate, reliable construction inspections of primary pressure boundary components and welds.
	High Temperature Gas Reactor (HTGR) Materials	The objective of this project is to advance necessary materials research, leveraging the Department of Energy's (DOE's) Nuclear Energy Research Initiative (NERI)-c selection and funding. The project also will contribute to a working roadmap that defines the research needs to ensure NGNP and GEN IV success.

Project Descriptions

New Nuclear Plant Deployment Program Model (NPDPM) (062886)

Issue

The new plant licensing and deployment process is a long and expensive process that involves working with regulators, designers, engineering architects, and a large variety and number of contractors. Planning is crucial to schedule and budget control, but there are no known integrated macro-tools for supporting decisionmaking and planning for new nuclear plant deployment. In addition, since new nuclear plants will likely incorporate new designs, a new licensing process, and new construction methods, there is no experience from which planners can develop project plans.

Description
The New Nuclear Plant Deployment Program Model provides a planning tool to describe, organize, present, and assess required applicant actions and decisions; schedule activity durations and logic relationships; perform critical path analyses; manage contracting and support requirements; and estimate resource requirement scenarios for the full span of licensing, design, and plant deployment. The New Nuclear Plant Deployment Program Model can also be used to study "what if" questions of particular interest for planning a new plant deployment project.

Value
- Supports complex planning for new nuclear plant deployment
- Satisfies a need for deployment experience, data, and other planning information
- Provides the only available front-to-back model schedule with documented assumptions
- Allows model users to support new plant deployment planning and provide feedback to EPRI
- Enables users to ask "what if" questions and study various licensing and procurement scenarios

How to Apply Results
Member planning staffs use the New Nuclear Plant Deployment Program Model to develop detailed site-specific deployment plans. The model also is used to perform trade-off studies of various deployment options and to assess the impact of inputs and assumptions on the overall schedule. An NPDPM working group, comprised of utility representatives involved in new plant deployment projects, provides feedback to EPRI for input into subsequent versions.

New Nuclear Plant Materials (052490)

Issue
Material degradation issues in new nuclear power plants must be actively managed to minimize operational impacts. New plant materials management matrices will be developed for the four proposed advanced light water reactors to limit plant deployment risk and incorporate lessons learned and materials research advances from the existing fleet into new designs.

One of the primary factors affecting materials degradation is residual stresses left during the fabrication process. Proper selection and control of welding processes can reduce or eliminate tensile stresses on the inside diameter surface of piping components. These tensile residual stresses can cause stress corrosion cracking and other failure mechanisms in nuclear plant piping. A group of welding and materials engineers, fabricators, and other industry metalworking experts will be consulted to develop recommendations and document best practices for welding plant components and for fabricating new plants.

Description
A materials management matrix (MMM) will be produced for three advanced light water reactor designs (AP1000, EPR, and ESBWR). The MMMs will list critical information for each of the components in the nuclear steam supply system (ASME Class 1 equivalent). These matrices will be living documents that can be used to manage material issues over the operating lives of the reactors. Other materials-related projects including welding best practices will be conducted as needed.

Value
- Assist in evaluating materials-related issues, which can significantly affect operating costs in existing reactor designs
- Ensure new plants are economically competitive over their operating life through more effective materials management
- Minimize tensile residual stresses through application of welding best practices

- Simplify management and evaluation of materials degradation and flaws
- Extend initiation time of many degradation mechanisms by eliminating or minimizing the tensile residual stresses in welds

How to Apply Results

The MMMs function as an ongoing roadmap to material issues for the life of the plant. They will be maintained by EPRI and updated periodically with assistance and feedback from vendors and plant owners. Members will use them to assist with purchase decisions and as an ongoing tool for optimizing inspection schedules and mitigation strategies.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Best Practices for Basic Weld Configurations: This product will document best practices currently used for welding plant components and procedures in fabricating new plants. A group of welding and materials engineers, fabricators, and other industry metalworking experts will develop recommendations. This product will characterize the critical attributes for common weld configurations; the best welding sequence to reduce/eliminate tensile residual stresses or create compressive stresses on the wetted surface of common weld configurations; the best parameters for post-weld heat treatment; the best practices for weld repairs that result in the most beneficial stresses to ensure leak-before-break and minimize tensile stresses on wetted surface of weld; and actions that can be taken to reverse tensile stresses after welding is complete.	12/20/2009	Technical Report
Materials Management Matrix - APWR: The MMMs function as an ongoing roadmap to material issues for the life of the plant. They will be maintained by EPRI and updated periodically with assistance from vendors and plant owners. They will be used initially by member utilities to assist with purchase decisions, but will have ongoing value, including use as a tool for optimizing inspection schedules and mitigation strategies.	12/20/2009	Technical Report
Materials Management Matrix - ABWR: The MMMs function as an ongoing roadmap to material issues for the life of the plant. They will be maintained by EPRI and updated periodically with assistance from vendors and plant owners. They will be used initially by member utilities to assist with purchase decisions, but will have ongoing value, including use as a tool for optimizing inspection schedules and mitigation strategies.	12/20/2009	Technical Report

Technology Transfer to New Nuclear Plants and URD Update

Issue

As members proceed with licensing activities for new plants, lessons learned from the operating fleet and from prior EPRI research and development programs must be incorporated into proposed designs. To mitigate risks associated with existing technology, this project seeks to transfer applicable EPRI technology into advanced plant designs and ensure new plants reflect the current knowledge.

Description

This project will transfer current and relevant information from prior EPRI research and development as well as EPRI- and industry-collected operating experience into new plant designs through updates to various sections of the Utilities Requirement Document.

Value

- Support development and implementation of a standardized set of requirements for building new plants that include the lessons learned from the operating fleet of plants and results of EPRI research and development programs
- Reduce risks and costs of deploying new nuclear units

How to Apply Results

EPRI, working with members and vendors, will engage and lead technology transfer activities. EPRI will provide an updated set of requirements via updates beyond the current Revision 8 of the URD. The updated information will be available to members and their vendors to support ongoing design activities.

New Nuclear Plant Equipment Reliability

Issue

Equipment reliability at nuclear plants starts with design and procurement and continues through construction and startup. When the plant begins operating, the level of success and cost associated with equipment reliability programs are directly related to the foundation established in the early stages of the plant's life.

While equipment vendors can focus on first costs, the owner/operator needs to consider first cost, operating cost, and plant revenue when making decisions. Limited actions have been taken to factor lessons learned from current equipment reliability programs into new plant projects.

Description

This project will develop numerous products to support enhanced equipment reliability programs. Appendix G to INPO AP-913, "Considerations for Building Equipment Reliability into New Plant Deployment," will be a primary guide for this project.

Value

- Establish a foundation for a highly effective operating plant equipment reliability program, leading to high-capacity factors and contained operations and maintenance costs
- Minimize implementation costs for equipment reliability programs through up-front incorporation into new plant designs rather than incorporating at a later date
- Incorporate owner expectations for equipment monitoring into initial project plans

How to Apply Results

Plant staff will apply lessons learned, guidelines, and recommendations from existing plants into equipment reliability programs for new plants

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Additional Standard Specifications for Commodity Items: This project will include development of additional standard specifications for construction commodity items. Standard specifications would include minimum technical and quality assurance requirements and will not be manufacturer-/supplier-specific in nature.	6/30/2009	Technical Update

Product Title & Description	Planned Completion Date	Product Type
Equipment Reliability for New Nuclear Plants - Lesson Learned from Operating Plants Final Single Point Reference: This product will address component classification, single-point vulnerabilities (SPVs), and equipment monitoring platforms; provide recommended criteria for critical component identification and SPV evaluations and treatment; provide recommended guidelines for applying equipment reliability principles in the design process (eliminating SPVs, reviewing operating experience prior to design, using predictive failure rates); and provide recommended guidelines for establishing unified monitoring for the plant.	12/20/2009	Technical Report

New Nuclear Plant Seismic Issues

Issue

The underlying generic seismic source model for the Central and Eastern United States (CEUS) is more than 18 years old and the Nuclear Regulatory Commission is on record as indicating that the model should be updated every 10 years. Also, recent NRC Requests for Information (RAIs) are challenging the source characterization used in EPRI's probabilistic seismic hazards analysis (PSHA), continuing the NRC trend away from its use of EPRI's baseline seismic hazard model.

Description

EPRI is updating a seismic hazard model for the Central and Eastern United States (CEUS) that will facilitate new plant siting and respond to regulatory concerns. An updated generic CEUS seismic hazard model will benefit several industry participants: a) nuclear power plant owners and developers that have submitted an ESP or COLA for NRC review in 2007 (or 2008) or will submit a COLA for a second unit in or after 2009; b) nuclear power plant owners and developers that will submit an ESP or COLA for NRC review in or after 2009; and c) operating nuclear power plant owners that must respond to issues resulting from NRC Generic Issue 199 (GI-199).

Value

- Realize significant time and resources through standardization and partnering
- Achieve stability in the seismic design of new plants
- Provide a consistent, stable basis for computing site-specific PSHA for a future time span that has been vetted by the NRC for members that will submit a COLA for a second unit in or after 2009 or members that will perform a site selection study or submit an ESP or COLA for a new plant site in or after 2009
- Provide licensing certainty during the three-year NRC review for members that have submitted an ESP or COLA
- Optimize selection of sites in the CEUS for future nuclear units by cost-effectively performing PSHA sensitivity studies upfront
- Provide important information for members that must respond to safety issues regarding NRC Generic Issue 199 (GI-199) for existing plants
- Inform decisions regarding the current state of knowledge incorporating different proponent interpretations in a non-regulatory environment using the approved Senior Seismic Hazard Analysis Committee (SSHAC) process
- Eliminate potential for multiple, possibly conflicting, interpretations of seismic sources by different consultants
- Avoid challenges to the EPRI-Seismic Owners Group (SOG) (1989) seismic source characterizations by NRC staff, its consultants. or interveners during the hearing process

- Minimize potential for duplication of effort because seismic hazard models for many CEUS sites have significant geographic overlap
- Reduce the opportunity for delays due to more conservative interpretations

How to Apply Results

- Members that have submitted an ESP or COLA for NRC review in 2007 (or 2008) or will submit a COLA for a second unit in or after 2009 will use the generic CEUS seismic hazard study to prevent unnecessary delays in the NRC licensing process if the EPRI-SOG (1989) seismic source characterizations continue to be challenged by NRC staff, its consultants, or interveners during the hearing process.
- Members that will submit an ESP or COLA for NRC review in or after 2009 will use the results from the generic CEUS seismic hazard study as input to its site selection study and to the PSHA for prospective new plant sites in the CEUS as part of the effort to develop a site-specific seismic design basis for ESP and COL applications.
- All members will use the generic CEUS seismic hazard study to respond to any safety issues resulting from NRC Generic Issue 199 (GI-199) for existing nuclear plants.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
EPRI CEUS Seismic Source Model Update: Draft technical report for regulatory review of a generic CEUS seismic source and source characterization model. This will be accomplished by updating the CEUS earthquake catalog, compiling new relevant geological and geophysical data, and updating CEUS seismic sources and seismic source characterizations.	12/22/2009	Technical Update

New Nuclear Plant Equipment

Issue

Due to demographic, technical, and regulatory factors, there will be increasing competition for fresh water supplies in the future. The electric power industry must anticipate how this water shortage risk will affect its long-term ability to operate thermal power generation assets. Power plant cooling is the largest user of water for both power plants with once-through cooling and those with evaporative wet cooling towers. Thus, it is logical to develop and apply water-conserving technologies that reduce withdrawals and consumption of fresh water for power plant cooling.

Description

The project will extend and complete the engineering and economic assessment of wet and dry cooling documented in EPRI Report 1005358, *Comparison of Alternative Cooling Technologies for U.S. Power Plants: Economic, Environmental, and Other Tradeoffs*. The project will evaluate the technical and economic feasibility of applying dry cooling technology to nuclear power plants, examine novel bottoming binary cycles, and conduct wind tunnel testing and numerical modeling evaluation of technology to improve the performance of dry cooling (air-cooled condenser).

Value

- Reduce dependency on water resources for future power plant sites
- Develop tools and information for performing research and development on cooling systems

How to Apply Results
The results of this work will be factored into future power plant designs to help improve water efficiency and reduce water usage. This work also may lead to additional studies to develop more detailed design information for specific cooling approaches, including dry cooling systems and systems using bottoming binary cycles. Finally, the enhanced simulation tools developed in this project will support future development efforts on plant cooling systems

New Nuclear Plant NDE

Issue
New nuclear power plants must comply with requirements for pre-service inspection (PSI) and in-service inspection (ISI) of pressure boundary components and supports in accordance with regulatory accepted codes and standards (for example, ASME Section XI). These requirements are typically deterministically based, but 90% of existing plants have transitioned to risk-informed methods for meeting PSI and ISI requirements.

In addition, nuclear power plants must comply with ASME Section III requirements for construction, pre-service and in-service volumetric inspection of the primary pressure boundary. The construction volumetric inspection ensures that the components and welds meet the applicable codes. Changes to ASME Section III could eliminate unnecessary repairs by allowing acceptance of fabrication flaws that are not structurally significant. This will require industry and regulatory confidence in the volumetric NDE methods that are used to detect and size fabrication flaws.

Description
EPRI's risk-informed in-service inspection methodology will be tested and refined for advanced plant designs. The goal would be to develop a single PSI/ISI program for each design (not site-specific) or define any issues and provide guidance where they may be site-specific requirements.

The project also will establish and operate the ultrasonic (UT) examination qualification programs that will be necessary to ensure accurate, reliable construction inspections of primary pressure boundary components and welds.

Value
- Enable timely and cost-effective compliance with regulatory requirements for construction inspection
- Facilitate regulatory acceptance of fitness-for-service philosophy, eliminating unnecessary repairs
    - Cost savings and elimination of delays during construction
    - Improved resistance to stress corrosion cracking during plant operation
- Reduce construction, inspection, and acceptance costs
- Reduce operating costs
- Shorten construction and turnover schedules by focusing resources on more important systems and components and incurring fewer regulatory actions

How to Apply Results
Members will have access to a regulatory-approved ISI methodology for use in new plant license applications. This also will support future operations and maintenance activities over the life of the plant.

Members will use the UT Qualification products in specifying certification levels and specialized qualifications for UT personnel in construction procurements. As a result of these deliverables, the necessary qualified UT personnel will be available to support new plant construction.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Technical basis for fitness-for-purpose acceptance standards for nuclear components and welds: Integration between EPRI and ASME Sections III (construction) and XI (inspection) to provide the technical basis for allowing acceptance of benign welding flaws by structural analysis	6/30/2009	Technical Report
Guidelines for component design and installation to facilitate optimized NDE: Guideline document containing design and installation parameters for inspection-friendly components. EPRI will communicate with plant designers to impart guidance for field installation and welding and facilitate application before installation begins.	12/20/2009	Technical Report
ASME Code definition of requirements: This product will review changes in ASME Section III that could eliminate unnecessary repairs by allowing acceptance of fabrication flaws that are not structurally significant. Nuclear power plants must comply with ASME Section III requirements for construction, pre-service, and in-service volumetric inspection of the primary pressure boundary. The construction volumetric inspection ensures that the components and welds meet the applicable codes. This will require industry and regulatory confidence in the volumetric NDE methods that are used to detect and size fabrication flaws.	12/20/2009	Technical Update
NDE Risk-Informed PSI & ISI Methodology - Test Cases for various designs: This product will review design-for-similarities approaches that incorporate lessons learned from existing plants (for example, spatial separation), risk metrics of new plants (for example,core damage frequency), and applicable codes and standards (for example, ASME SIII, SXI). These approaches can then be used to revise or develop new methodologies as required for classifying applicable plant systems and components for future licensee approval submittals, eliminating the need for plant specific review. The product will document the methodology, plant-specific application, and regulatory approval process.	12/20/2009	Technical Report

High Temperature Gas Reactor (HTGR) Materials

Issue

New sources of energy are being developed to alleviate two key challenges facing all industrialized and developing countries: increased energy security to improve national and global security and reduced carbon footprint in all economic sectors to address manmade contributions to global climate change. One such energy source is the high-temperature gas reactor, which can extend the use of improved nuclear technologies into energy sectors beyond the electricity generation.

Description

EPRI is co-funding research by the NERI consortium, which aggregates advanced materials development research activities by several prominent universities focused on next-generation energy systems such as a hydrogen-based economy.

Value

- Support possible transition to a “hydrogen economy,” in which nuclear energy is an essential technical component
- Provide the technical basis to ease public acceptance of the hybrid hydrogen/electric nuclear power plant in view of the perceived risk

How to Apply Results

Member awareness of material advances and research needs confronting development of high-temperature gas reactors and other advanced energy systems