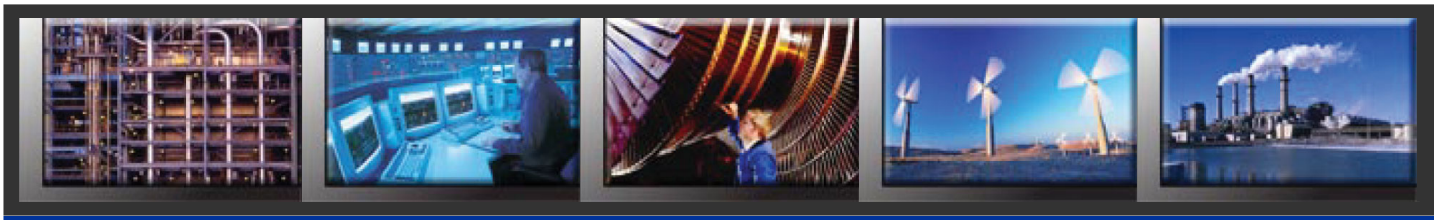
EPRI ELECTRIC POWER RESEARCH INSTITUTE

Generation Sector Update



A Report from EPRI's Generation Sector **February/March 2009**

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DEAR EPRI GENERATION MEMBERS

EPRI's advisory process is unique and is at the heart of our collaborative model. Our member advisors have helped assure that our R&D portfolio is kept relevant and impactful. Despite the fragile economy and cost reductions within your companies, it was heartening to see the continued high level of participation from both our domestic and international members at our recent Winter Program Advisory and Council meeting in San Diego.

At this meeting, we were able to revisit industry needs and priorities which drive our R&D planning effort. Despite the recent global economic downturn, the political changes and regulatory uncertainties which face our industry, the discussions reaffirmed the importance of our research priorities – the continued focus on maintaining the viability of the existing generation fleet as an option, and the reduction of the technical uncertainties associated with new generation options. To that end, carbon capture and storage, environmental controls of other emissions at minimum cost, and the cost effective means to manage damage mechanisms affecting our current fossil fleet have been reaffirmed as high priority needs, and continues to form the backbone of our portfolio. These areas of emphasis are well represented in this Sector Update.

Our next formal meeting with you is in Boulder in September. In the meantime, many of our programs will have webcasts, meetings or other means to keep you informed of research progress and to obtain your feedback and input on research needs.

Have a terrific Spring.

Bryan Hannegan
Vice President, Environment and Generation
bhannegan@epri.com
650-855-2858

Stu Dalton
Director, Generation
sdalton@epri.com
650-855-2467

Norris Hirota
Director, Generation
nhirota@epri.com
650-855-2084

CoalFleet for Tomorrow-Future Coal Generation Options (Program 66)

Updated UDBS supports design and permitting of IGCC plants.

Report includes lessons learned and input from experts and equipment.

Version 8 of the CoalFleet User Design Basis Specification (UDBS) now is available for download from www. epri.com *(EPRI document #1015686)*. The UDBS defines the major specifications needed to contract for multiple configurations of 600- and 800-MW output commercial IGCC power plants, using gasification processes and combustion turbine equipment from several manufacturers that offer equipment with commercial guarantees. The specifications are flexible and allow adjustment of the designs to accommodate various coal types and other basic options to match the needs of different power companies. The designs also provide a swap-out choice of environmental cleanup systems tailored to three levels of licensing constraint, including CO_2 capture.

The UDBS has many other uses. It incorporates a host of lessons learned from existing plants, and its coverage of safety issues and lists of applicable regulations can be helpful during the permitting process. Also, the UDBS can serve a teaching tool, providing advice on training programs and serving as an industry document to facilitate the exchange of information among plant owners, vendors, and regulators.

More than two dozen experts from the IGCC Design Guidelines Working Group wrote this document, with the cooperation of IGCC equipment suppliers, plant designers, and engineering, procurement, and construction or construction management companies. This eighth version includes seven gasifiers (air- and oxygen-blown), nine gas turbine models, 17 separate IGCC configuration descriptions for plants without and with CO_2 capture, an overview of CO_2 transport and deep geologic storage issues, and a new section on project planning and management. For more information, contact George Booras (gbooras@epri.com, 650-855-2471).

Advances in gasification technologies are detailed in new report.

China leads the way in coal gasification activity.

From 2004 to date, IGCC plants with commercial guarantees have been offered by GE Energy, ConocoPhillips (COP) and Shell. However, in 2007-8, other gasification technologies also advanced to the point of commercial offerings, and they're detailed in EPRI's recent *Gasification Technology Status Report* (1015683). Included are updates on Mitsubishi Heavy Industries' (MHI) demonstration of its technology at a 250-MW plant in Japan; Siemens' gasification technology in the 500-MWth (1600-mt/d) size; Uhde's Prenflo technology for IGCC application at the 1000-MWth size; and the air-blown KBR technology planned for use on Southern Company's 600-MW IGCC proposed project in Mississippi.

Worldwide, the main activity on coal gasification is centered in China, where it has strong support from the central government and both imported and domestically developed technologies are being widely deployed. The report includes information on GE's 40 licenses and more than 20 plants in operation in China, as well as Shell's 18 licenses and 11 plants in operation; the Lurgi dry ash technology; Siemens, BGL and SES gasifiers, and several different gasification technologies in domestic development in China (there are 13 projects using 33 gasifiers in operation or planned in the next two years, as well as three planned IGCC projects based on domestically developed gasification technologies). Some experts predict China will offer its technology in the wider marketplace abroad. For more information, contact Neville Holt (nholt@epri.com, 650-855-2503).

Major coal generation technologies, biomass and gasification featured in report.

Operating Experience, Risk, and Market Assessment of Clean Coal Technologies: 2008 (1015679) covers developments in the three major coal-based power plant technologies, pulverized coal (PC), circulating fluidized beds (CFB), and integrated gasification combined cycles (IGCC). The PC section discusses ultra-supercritical plants (1112°F-600°C) being built in Germany using bituminous coal and lignite, and two plants proposed for deployment in the U.S. using sub-bituminous coal. Two supercritical CFB plants also are discussed, as well as smaller biomass-fired projects being developed in the U.S. in response to renewable portfolio standard (RPS) requirements.

The gasification developments include new commercial offerings from MHI, Siemens, KBR and Uhde, a large number of plants being built in China – mainly for chemicals – and an IGCC power plant under construction in the U.S. For more details contact John Wheeldon (jowheeld@epri.com, 205-670-5857) and Neville Holt (nholt@epri.com, 650-855-2503).

Annual test results highlight 2008 power systems research.

Recent modifications and results of a variety of tests at the Power Systems Development Facility (PSDF) in Wilsonville, Alabama are the subject of *Test Results 2008* (1015691). The gasifier was modified to increase the mean solids residence time in the reaction zone and raise gasification efficiency. Testing with bituminous coal confirmed the effectiveness of these modifications by achieving carbon conversions as high as 96 percent (compared to the less than 90 percent achieved previously).

The syngas slip-stream test loop was used extensively to test catalytic candles to promote the water-gas shift reaction; a hydrogen-selective carbon molecular sieve; CO_2 removal from syngas using solvents; warm gas sulfur sorbents and hydrocarbon cracking catalysts; and DOE-NETL's solid oxide fuel cell test module.

For more details contact John Wheeldon (jowheeld@epri.com, 205-670-5857).

Work on tunable diode laser sensor for gasifiers progresses.

New technology could help make gasifiers more reliable.

A recent EPRI-sponsored study demonstrated the potential for using tunable diode laser (TDL) absorption sensors for real-time measurement of carbon dioxide (CO_2) water vapor (H_2O) and temperature in high-pressure coal gasification conditions. The demonstration was conducted by researchers at Stanford University, which has an extensive history of developing TDL sensors for a variety of practical applications.

Successful testing of the laser sensor in a pristine lab environment on room temperature mixtures of CO_2 at pressures up to 10 atmospheres has been described in an EPRI report, *Program on Technology Innovation: Laser-Based Sensors for Monitoring Coal Gasifiers* (1016213). For testing in more realistic conditions, EPRI arranged for the Stanford team to take its sensor to a pilot-scale fluidized bed gasifier running on black liquor at the University of Utah in January 2009.

The sensor was able to measure both temperature and H_2O vapor concentration in the gasifier over a wide range of particulate loading. This indicates this method might be used in commercial scale gasifiers to measure and control temperature and syngas composition, which can help lead to more reliable gasifier operation by promoting longer life of the refractory lining and few slagging issues. For more information on this Technology Innovation project, contact Rob Steele (rsteele@epri.com, 704-595-2025).

CO2 Capture & Storage (Program 165)

EPRI comments on EPA's proposed Underground Injection Control (UIC) regulations for CO2 geostorage.

On July 25, 2008, EPA proposed regulations for CO_2 geostorage in the Federal Register, with comments due by December 23, 2008. The proposed rule adds a new class of wells, Class 6, for CO_2 storage and sets standards for characterizing, permitting, monitoring, closing and financial requirements for a site used for subsurface injection of CO_2. As with all UIC regulations, the goal of the regulation is to protect underground sources of drinking water (USDW).

In its comments, EPRI identified a number of technical issues and areas needing clarification. Prior to submitting the comments, EPRI's staff shared them with several advisors to Program 165 and the Environment Sector's Land and Groundwater Area who have special expertise in geology and/or UIC rules. For more information, contact Rob Trautz (rtrautz@epri.com, 650-855-2088).

Report provides overview of regulations on CO2 transport and storage.

Regulation and Permitting of Carbon Dioxide Transport and Geologic Sequestration (1016854) provides a comprehensive review and analysis of U.S. regulations that will have a direct impact on permitting and commercial-scale deployment of CO_2 transport and sequestration projects. The report focuses on specific regulations, including pipeline rules and the U.S. Environmental Protection Agency's (EPA's) proposed rules for characterizing, operating, monitoring and closing CO_2 geologic sequestration wells.

Carbon dioxide sequestration projects currently must cope with a patchwork of state and federal regulations governing CO_2 transport and injection. The EPA's proposed rule is designed to protect drinking water sources and does not address important issues such as ownership of the pore space used for sequestration, financial responsibility, and long-term care. Pilot-scale projects have been able to obtain injection permits fairly readily but the success of full-scale sequestration projects will depend on resolving the policy issues as well as implementing appropriate technical standards. For more information, contact George Offen (goffen@epri.com, 650-855-8942).

New EPRI results cover the CO2 spectrum from capture technologies to impacts on groundwater.

Several EPRI reports were recently published and available for download:

Program on Technology Innovation: Post-Combustion CO2 Capture Technology Development (1016995)

Report presents profiles on over 50 processes and includes a primer on gas separation fundamentals.

Findings from EPRI's two-year Technology Innovation project to identify, review and accelerate promising CO_2 capture technologies are documented in this report, which begins with a primer on gas separation, with an emphasis on the minimum energy of separation from a thermodynamic basis. This provides a benchmark against which candidate technologies were compared. The report also describes each general approach to CO_2 separation (absorption, adsorption, membranes, etc.) and the development and performance trends for each type.

Profiles of each capture technology investigated are included, as well as the methodology the EPRI staff used to filter and rank these technologies for consideration for funding assistance or encouragement via other means (e.g., letters of support in proposals for government funding). Each technology also was assigned a Technology Readiness Level (TRL) ranking – a relatively new tool (conceived by NASA and adopted by DoD and DOE) that can be used to compare via a single, consistently-defined, numerical rating, the maturity of different technologies under development. For more information, contact Brice Freeman (bfreeman@epri.com, 650-855-1050) or Abhoyjit Bhown (abhown@epri.com, 650-855-2383).

CO2 Health Effects in Wildlife Species (1018283)

This report, along with previously documented information on the effects of CO_2 on humans, laboratory animals, and domesticated animals, provides critical information necessary to conduct a risk assessment for CCS. Currently, there are significant gaps in knowledge regarding the toxic effects of CO_2 on wildlife species. Analysis of the data available led the researchers to conclude that each animal grouping within each environment requires individual assessment for the risks associated with CO_2 exposure. For more information, contact Sharan Campleman (scampleman@epri.com, 650-855-2331).

Carbon Dioxide Compression and Transportation (1016794)

The state of the art in CO_2 compression and transportation in the United States and Canada is summarized in this document. The primary focus is on compression because it imposes a significant cost and energy penalty on a power plant that implements carbon capture and storage. The report also documents the state of the art of CO_2 pipeline transportation in these two countries. For more information, contact Rob Steele (rsteele@epri.com, 704-595-2025).

Preliminary Evaluation of CO2 Impacts on Shallow Groundwater (1015848)

This report presents preliminary results from an ongoing field, laboratory, and modeling investigation to determine if injected CO_2 can have an adverse impact on potable groundwater in the unlikely event that CO_2 migrates from the injection reservoir into an underground source of drinking water. Early results from shallow injection tests show increases in the concentrations of some common inorganic species but virtually no changes in trace metal concentrations. For more information, contact Rob Trautz (rtrautz@epri.com, 650-855-2088).

Public Perceptions of Carbon Capture, Sequestration, and Other Carbon-Reducing Technologies (1015847)

Could an educational technique improve the public's ability to make informed decisions on carbon capture and storage (CCS), relative to other future power generation options that also reduce carbon emissions from the electricity industry? The initial results of a study suggest that, after the educational technique is used to provide a balanced view of CCS, participants may prefer future scenarios that include CCS over portfolios that do not. For more information, contact Brice Freeman (bfreeman@epri.com, 650-855-1050).

CO2 Capture and Storage Newsletter – Issue 4 (1018653)

This issue of EPRI's CO_2 Capture and Storage Newsletter includes highlights of four meetings held in late 2008:

- DOE's Regional Carbon Sequestration Partnerships meeting, Pittsburgh, PA (October)
- The Ninth Annual MIT Carbon Sequestration Forum, Cambridge, MA (October)
- Stanford's Global Climate and Energy Project (GCEP), Stanford, CA (October)
- IEA's Ninth Greenhouse Gas Technology (GHGT9) conference, Washington, DC (November)

For more information, contact Richard Rhudy (rrhudy@epri.com, 650-855-2421).

CO2 capture selected as one of 11 strategic program areas by EPRI's Office of Technology Innovation (TI).

Projects accelerate search, qualification, and development of lower-cost, lower-energy-penalty CO2 capture.

A long-range EPRI R&D program, titled "Alternative CO_2 Capture Technologies," aims to assist and accelerate development of next-generation CO_2 capture technologies. The program received $2.6 million funding for 2009, with additional funding planned in future years depending on research results and progress. These funds will support the following four projects this year:

- Participation in a 10-year consortium at the Center for Applied Energy Research (CAER) at the University of Kentucky, to support the development and evaluation of a number of solvents, sorbents, or membranes. CAER will use its pilot absorption/regeneration loop, which will be fed by flue gas from a pilot combustor to conduct small-scale screening tests. Initial CAER concepts include a catalyst to accelerate CO_2 capture by the solvent and a membrane to separate the carrier liquid from the solvent prior to regeneration.
- Participation in a 10-year effort at Southern Company's Plant Gaston in system-level demonstrations for promising CO_2 capture technologies at scales beyond laboratory proof-of-concept and up to 2 MW field pilot, including pre-, post-, and oxy-combustion.
- A 5-year effort to target proof-of-concept or pilot testing for high-risk, high-reward CO_2 capture technologies at various locations/labs (including universities). This will enable EPRI to support the development and evaluation of processes that cannot be accommodated by CAER or already have found a test location.
- A 3-year simulation and modeling effort internal at EPRI to guide process developers and support evaluations.

For more information, contact Abhoyjit Bhown (abhown@epri.com, 650-855-2383).

Two capture processes are reviewed.

One is mineralization, other is solvent enhancement, showing range of approaches being developed.

EPRI recently investigated an accelerated limestone weathering concept developed by Lawrence Livermore National Laboratory (LLNL) that reacts flue gas CO_2 with seawater or brine to form carbonic acid. The reactor can either be a spray tower or sparging design. The acidified water then is reacted with pulverized limestone to form aqueous bicarbonate, which is discharged to the ocean or saline aquifer. This is a "once-through" process

that relies on a continuous supply of both water and fresh limestone and accelerates a process that occurs naturally over a very long time period. EPRI is working with the principal inventor to study the energy and mass balances (availability of the required amount of limestone), environmental acceptability, and potential market size.

Stabilized enzyme catalyst is an enabling technology being developed by Akermin to enhance CO_2 capture in solvents. Carbonic anhydrase (CA) is a naturally occurring enzyme that catalyzes the reaction of CO_2 and water. The company uses a proprietary process to form a protective polymeric barrier around CA enzymes, which allows CA to be used at temperatures that normally would degrade the enzyme. When used in an absorption-based capture system, CA improves the reaction kinetics of slower solvents that otherwise have beneficial properties. Akermin is conducting experiments using its stabilized enzyme with potassium carbonate, which has a heat of regeneration several times lower than MEA. EPRI staff is continuing due diligence on this unique capture technology. For more information on either process, contact Brice Freeman (bfreeman@epri.com, 650-855-1050).

OPERATIONS AND MAINTENANCE

I&C and Automation for Improved Plant Operations (Program 68)

Asset Fault Signature Database Functional Specification document now available.

A new EPRI report, *Experience-Derived Fault Signature Database Functional Specification* (1015713) describes the functional specification for a proposed Asset Fault Signature (AFS) database to archive the fault signatures used by diagnostic software in arriving at a diagnosis. More specifically, this report focuses on the functional specification to define the experience-derived fault signatures that have their basis in actual damage or failure events that have been observed in power plant operation and documented for this use. A companion report, *Design Derived Fault Signature Database Functional Specification* (1015723), describes a second type of fault signatures – design-derived – that are based primarily on knowledge of equipment failure modes and effects. For more information please contact Aaron Hussey (ahussey@epri.com, 704-595-2009).

Maintenance Management and Technology (Program 69)

New report looks at differences between maintenance processes for various classes of equipment.

An Integrated Approach to Improved Plant Reliability (1015717), released in December, examines current strategies for maintaining reliability both of major fossil plant components as well as balance-of-plant equipment. Program advisors recently discussed the need to better integrate their maintenance programs, which often rely on corporate specialists for maintenance of major components, and plant staff for balance of plant equipment.

This report first presents a standard maintenance strategy that focuses on condition-based maintenance, then examines how this common strategy is applied in today's fossil industry. Reasons for lack of maintenance program integration at fossil plants are examined from both a technical as well as organizational perspective. Finally, the report presents a vision for a common maintenance strategy in terms of the attributes, barriers, and steps to achievement.

This project is intended to be the first in a series of future research efforts intended to explore and guide member companies toward improved plant reliability through increased integration. Starting in 2009, the Fossil O&M program area will be working with the Major Component Reliability program area on joint projects with the goal of improved utilization of major component reliability research results into plant operations and maintenance procedures. For more information, contact Steve Hesler (shesler@epri.com, 704-595-2183).

Fossil Maintenance Applications Center (FMAC) (Program 104)

Exelon uses EPRI PM Basis Database to pilot maintenance optimization.

Goal is optimized current resources, increased reliability.

EPRI members have used the EPRI Maintenance Templates as a standard for nearly two decades, but some have found the templates to be too resource-intensive to be applied effectively. In response, EPRI developed Preventive Maintenance Basis Database (PMBD) Implementation Experience (1016920) to show companies how to use the analytical tools within the PMBD (Product # 1014971) to balance PM tasks against failure modes and develop a customized program for individual reliability requirements.

In January 2009, Exelon started a fleet-wide initiative to improve its maintenance task effectiveness by piloting the PMBD-based process at a Pennsylvania plant. EPRI experts worked with Exelon staff to help them use PMBD to analyze its system and adjust maintenance tasks based on a number of criteria (criticality, duty cycle, operating severity, available resources and technology). Exelon will evaluate the experience at the pilot plant and create criteria based on the capabilities of each system – optimizing current resource outlays for increased reliability. This will be the first use of this next-generation approach in maintenance task selection. EPRI Fossil Maintenance Applications Center (FMAC) partially funded the effort and will publish a technical update later this year. For more information, contact Justin Thibault (jthibault@epri.com, 704-595-2103).

Operations Management and Technology (Program 108)

Guides help plant managers improve plant operations.

EPRI looking for companies to implement CAP programs.

Corrective Action Program Guideline (1015838) provides fundamental guidance on establishing a comprehensive program to manage a wide range of corrective actions in a fossil power plant. Effective corrective action programs (CAPs) are a cornerstone for achieving steady improvement in plant operations. Plant managers who effectively organize the wide variety of issues resulting from fossil operation can foster an environment of continuous improvement. This program guide helps plant managers understand how to document, prioritize, investigate, develop corrective actions, and review for effectiveness issues associated with all aspects of plant operation.

EPRI is interested in organizing a collaborative of member companies who would like to implement the guidance in the report. Collaborative economies can be achieved by working with several members jointly to train members' staff on the guide and advise them on implementation steps. Further value can be obtained by members' shared information and lessons learned as the group implements the same guidance over a number of plants and companies. For more information, contact Wayne Crawford (wcrawford@epri.com, 704-595-2233).

Implementation of alarm management guidelines results in changes.

Three alarms account for more than 35,000 annunciations.

A supplemental project to help one member implement the *EPRI Alarm Management and Annunciator Application Guidelines* (1014316) brought almost immediate results. The initial scope of alarm documentation and rationalization has been completed, with more than 4,000 points reviewed by the team. Highlights of the results include reducing the number of Priority 1 alarm devices by approximately one half; three alarms were identified to have contributed to over 35,700 annunciations over a two month period; and improvement of these three involved a setpoint change, a process improvement, and one alarm was determined to be unnecessary. For more information, contact Wayne Crawford (wcrawford@epri.com, 704-595-2233).

MAJOR COMPONENT RELIABILITY

Boiler and Turbine Steam and Cycle Chemistry (Program 64)

EPRI guidelines offer options for controlling corrosion in air-cooled condensers.

There is a growing trend today for more new and existing generating facilities to include air-cooled condensers (ACCs) as a replacement for more efficient water-cooled condensers (WCCs). In addition, recent drought conditions in the southeastern United States and the environmental impact of water use in new plants have highlighted water usage as a critical future challenge for the power industry. Understanding and controlling the corrosion products emerging from an ACC can be critical for plants in controlling the overall plant cycle chemistry and thus the plant's availability, reliability, and performance.

EPRI has published *Interim Guidelines for Control of Steamside Corrosion in Air-Cooled Condensers of Fossil Units* (1015655), offering the first documentation of the possible sources of corrosion and flow-accelerated corrosion in ACCs. The guidelines also provide the best available information on cycle chemistry treatments and equipment to manage the issues of corrosion and corrosion products emerging from ACCs. These guidelines provide the required changes in pH control and feedwater filtration to accommodate corrosion control in association with other types of chemistry control requirements and are applicable to all types of fossil boilers and HRSGs.

The project team of experts and technical advisors, experienced in the operating chemistries and operational problems with ACC, researched available literature and visited multiple installations worldwide to gather operating data and experience in the operation of ACCs. Contacts included end users, plant designers, and ACC manufacturers. A key contact was the ASME Power Plant and Environmental Chemistry Committee, which has a working group investigating corrosion of ACCs and possible mitigation strategies. The findings were assessed by the project team to provide interim guidance and the best available information as well as to identify further research needs. For more information, contact Jim Mathews (jmathews@epri.com, 704-595-2044).

ENVIRONMENTAL CONTROLS

Combustion Performance and NOx Control (Program 71)

Members identify R&D results and priorities during webcasts.

During end-of year program webcasts for P71 and P73, Post Combustion NOx Control, EPRI members and staff focused on summaries of products delivered in 2008 and prioritization of 2009 work. For P71, the highest priorities included testing of weld overlays and coatings to combat fireside corrosion and circumferential cracking, novel slag management techniques, mercury reduction with combustion modifications, and heat rate impacts on environmental controls. Highest priorities for P73 included performance and economics of SCR catalyst regeneration, SCR catalyst management issues, and mitigation of large particle ash. For more information, contact Tony Facchiano (affachia@epri.com, 650-855-2494).

The effect of orifice location on the flow split of particles, the physics of layout in horizontal piping, and the preliminary results from the evaluation of an online fineness probe were the top three topics during a recent Program 71.004 (Coal and Air Flow) project review webcast. Upcoming evaluations include those on a specialty elbow designed to reduce erosion and an adjustable coal splitter/controller. For more information, contact Jose Sanchez (josanche@epri.com, 650-855-2580) or Sam Korellis (skorellis@epri.com, 704-595-2209).

Navigant representatives described their benchmarking capabilities, along with their recent use of recursive partitioning to better assess the data, during a technical webcast on benchmarking power plant performance, sponsored by Heat Rate and Cost Optimization (P71.005). More than 30 participants from 11 member utilities were on hand. Ameren staff discussed their efforts to benchmark performance using Navigant, CEMS data, and the company's performance monitor. For more information, contact Jeff Stallings (jstallin@epri.com, 650-855-2427) or Sam Korellis (skorellis@epri.com, 704-595-2209).

Three-day conference on heat rate offers insights on plant performance improvements.

More than 170 participants looking to address problems with power plant performance and find cost-effective solutions for achieving and sustaining heat rate improvements were on hand for the 16th annual Heat Rate Improvement Conference, hosted in February by Public Service New Mexico in Albuquerque. This conference has become the focal point for industry experts to convene and address new developments and research needs for power plant heat rate improvement throughout the industry.

The seven sessions included a panel on plant performance improvements. Multiple presentations covered boiler and turbine performance, performance monitoring, heat exchangers, plant performance improvements, and intelligent sootblowing. For more information, contact Jeff Stallings (jstallin@epri.com, 650-855-2427) or Sam Korellis (skorellis@epri.com, 704-595-2209).

Post-Combustion NOx Control (Program 73)

EPRI to test new SCR catalyst formulation.

Two projects are evaluating the performance of a near commercial SCR catalyst designed to enhance the oxidation of elemental mercury (Hg^o) while maintaining high deNOx levels and low SO_2 to SO_3 conversion. One project will be conducted at Gulf Power's Mercury Research Center (5 MW equivalent pilot SCR reactor) where halogens will be added to determine the lowest levels required to maximized reactor oxidation potential. In a parallel project, the catalyst material will be tested at a plant burning 100% PRB fuel. For more information, contact Alex Jimenez (ajimenez@epri.com, 650-855-2051) or Chuck Dene (cdene@epri.com, 650-855-2425).

Integrated Environmental Controls (Hg, SO2, NOx and Particulates) (Program 75)

Energy & Environment Conference & Expo (EUEC), co-sponsored by EPRI, expands focus to climate-related issues.

Most mercury papers essentially expand data base, but a few present new findings.

The 12th Annual EUEC conference in Phoenix, Arizona, February 2-4, provided a number of new insights in mercury R&D, including:

- Mercury removals across the board in reported field tests ranged from 80% to 97% (short-term tests). Differences in mercury capture performance from site-to-site continue to depend largely on coal constituents and air pollution controls.
- There was no consensus on how much SO_3 in the flue gas could be tolerated at plants capturing mercury via carbon, whether unburned carbon in the ash or injected activated carbon. No effects levels ranged from 2 ppm to 10 ppm SO_3. Generally, the addition of alkali sorbent to remove SO_3 from the flue gas helped the capture of mercury by carbon, but a few experimenters did not see the same value.
- A growing number of papers showed the benefit of injecting the activated carbon upstream of the air preheater. Several provided data indicating that 50% less sorbent is needed with upstream injection to achieve a given mercury capture. One or two papers also presented results showing the benefits of on-site grinding of the sorbent, but did not present corresponding economics to justify the costs of the grinding equipment.
- A few papers reported that they had not measured any particulate matter (PM) increase when injecting sorbent. Although others (including EPRI) have reported the same finding before, the data are not consistent.
- Evonik (subsidiaries were formerly Steag and Degussa) reported success injecting activated carbon in the duct ahead of an FGD and also adding it to the FGD slurry recycle loop.
- B&W reported on its success with its additive to prevent FGD re-emissions at a 400-MW plant burning eastern bituminous coal and equipped with a limestone forced oxidation scrubber.
- Southern Company reported that it had found significant increases in mercury removal across the pilot CT-121 scrubber at its Mercury Research Center with the addition of chlorine or bromine.
- Mazyck Technology Solutions reported on bench-scale studies by a team lead by David Mazyck at the University of Florida that showed very high mercury capture rates by his proprietary silica-titania composite material stimulated by UV light. EPRI had provided feedback to the developer on application requirements for the power industry.
- Siemens reported that it is developing a sorbent for capturing mercury, but are still in the laboratory stage.
- Both Nalco-Mobotec and Solvay indicated they had measured mercury removals ranging from 70% to 90% with alkali sorbent injection.

For more information, contact Ramsay Chang (rchang@epri,com, 650-855-2535).

Novel activated carbon fiber cloth shows promise as potential mercury filter.

Two samples had mercury capacities much greater than powdered activated carbon.

Five activated carbon fiber (ACF) samples have been prepared, with a goal of developing high-capacity carbon cloth for potential use as a mercury filter. This could offer an option for mercury capture without impacting fly ash use. The ACF materials are sulfur-impregnated activated carbon fiber cloth using a special impregnation technique. Of the five samples tested in the laboratory (simulated flue gas), two showed mercury capacities much greater than commercial powdered activated carbons. EPRI plans to produce larger quantities of these promising carbon clothes for pilot testing in actual flue gases. For more information, contact Ramsay Chang (rchang@epri.com, 650-855-2535).

Annual reports on mercury control available for download.

One report presents recent findings on the fate of mercury captured in FGDs; the other provides updates on injection based capture technologies.

Mercury Control Update (1015761) contains a detailed description of full-scale activated carbon injection testing at four power plant sites, a summary of EPRI's work on carbon specifications, and an update on bromine balance-of-plant impacts. *Update on Mercury Capture by Wet FGD* (1015760) presents recent results on three projects: (1) field measurements to determine how absorbed mercury partitions between the FGD liquor and solids in the absorber and in downstream dewatering processes and how this mercury partitioning impacts mercury re-emissions; (2) a 200-MW-scale demonstration of a low-temperature mercury oxidation catalyst installed to enhance mercury capture by the FGD at this PRB-fueled power plant; and (3) bench scale tests to determine the reactions (and associated rates) between absorbed mercury and solids in the FGD liquor that control the changes leading to re-emissions.

For more information on 1015761, contact Ramsay Chang (rchang@epri.com, 650-855-2535); for 1015760, contact Richard Rhudy (rrhudy@epri.com, 650-855-2421).

Methodology developed to identify start-up/shutdown/malfunction emission excursions.

Assessment of emissions during these events may help power plants avoid compliance issues.

Because most new units (those permitted since January 2000) are required to meet both short-term (3-hour and 24-hour) and long-term (≥30 days) emissions limits, power companies need guidance on maintaining compliance during start-ups, shutdowns, and malfunctions (SSM). EPRI is analyzing emissions data reported to the EPA to determine if SSM periods can be identified from the data and how emissions behave during these events. A follow-on effort will seek the causes for any excursions during these transients.

A review of the emission limits for the 40 units permitted since 2000 indicated that typically the 3-hour-average limit is 150-175% of the long-term limit, while the 24-hour-average limit is 125-150% of the long-term limit. EPRI developed a methodology for determining SSM events and validated it on emissions reported in the EPA-CAMD database. The methodology identifies periods of missing heat input data and looks 36 hours before and after to determine if the event constitutes a shutdown or start-up. The methodology was tested on a single unit for which the contractor had first-hand knowledge, and it provided the expected results. Analysis of all 40 units has begun. For more information, contact Chuck Dene (cdene@epri.com, 650-855-2425).

Inherent mercury removals measured across a fabric filter at a plant firing a low-sulfur bituminous coal.

High unburned carbon levels produced removals up to 97%.

Baseline mercury removal measurements were conducted at a 150-MW unit that burns a low-sulfur Eastern bituminous (LSEB) coal and is equipped a pulse-jet fabric filter (PJFF) for particulate control. Short-term total vapor-phase mercury (TVM) removals across the PJFF ranged from ~70% to >95%, with removals greater than 90% requiring plant loss-on-ignition (LOI) above 20%. Coal sulfur and chlorine content also appeared to affect the mercury removal effectiveness. For units in which the LOI is not very high, small amounts of supplemental activated carbon injection may be sufficient to maintain high mercury removals. For more information, contact Ramsay Chang (rchang@epri.com, 650-855-2535).

PMscreen™ shows promise for particulate polishing.

Proof-of-concept testing shows up to 50% additional particulate removal at modest pressure drop.

EPRI's PMscreen concept was tested at the Pawnee Station using a 160 acfm device with a 1 ft^2 filter and a rotating design for continuous cleaning. PMscreen was conceived to provide a low-cost, low-pressure-drop upgrade to an ESP to capture uncollected particulate. While the primary motivation for developing PMscreen was to counter the potential increase in particulate matter (PM) emissions with activated carbon injection (ACI), the concept also can also be used as a polishing device for an underperforming ESP that needs to cut emissions by up to 50%. The Pawnee tests used a stainless steel mesh filter material rotated continuously to keep it clean and run for three days. Removal performance was near 40% with ACI and somewhat higher without. Average pressure drop across the filter was maintained at < 3inch water at ESP gas velocities. These results show the viability of a low-cost polishing filter concept for maintaining outlet particulate emissions from a power plant adding ACI. Larger tests are planned for the 1 MWe pilot ESP unit at Alabama Power's Plant Miller. For more information, contact Ramsay Chang (rchang@epri.com, 650-855-2535).

Validation of REI mercury prediction model completed.

Exercise (first-of-its-kind) showed capabilities and additional development needs of the REI model.

For several years EPRI has been supporting Reaction Engineering, International (REI) and Niksa Engineering Associates (NEA) as they refine their models for predicting mercury speciation and emissions. Recently, EPRI provided the modelers with input data from unpublished measurement campaigns at eight sites, but no speciation and emission results, and asked them to provide their predictions of these parameters. EPRI then compared those predictions with the measurements. Based on this small number of runs, the REI model appeared to predict mercury emissions from controlled units (co-benefits or ACI) with reasonable accuracy but typically underpredicted inherent capture by fly ash and ESPs. The validation results are presented in *Validation of the REI Mercury Prediction Model* (1015763). For more information, contact George Offen (goffen@epri.com, 650-855-8942).

Laboratory tests show selenium oxidation in a wet scrubber is impacted by trace species in the slurry.

Important because oxidized selenium is hard to remove from scrubber blowdown.

Under this Technology Innovation (TI) project, EPRI is finding that a number of species impact the oxidation of Se in FGD systems. Experiments to better understand these relationships are under way. Most recent tests are focusing on Mn, Co and Fe. Interactions with a scrubber performance-enhancing additive, dibasic acid, also are being investigated, to determine if these contribute to unknown selenium species that have shown up in some FGD systems. For more information, contact Chuck Dene (cdene@epri.com, 650-855-2425) or Paul Chu (pchu@epri.com, 650-855-2812).

Particulate & Opacity Control (Program 76)

Laboratory tests of hydrated lime injection samples produce unexpected results.

Sorbent/ash mixture resistivity was predicted by existing correlations, average particle size decreased, and percentage sub-micron particles also decreased.

Tests at a plant injecting hydrated lime in the furnace for SO_2 control showed the expected trends of decreasing SO_2 emissions, increasing particulate emissions, and increasing opacity with increasing lime injection rates. However, the subsequent laboratory tests of samples collected at the site produced a few surprises:

- The resistivity of the ash/sorbent mixtures could be predicted accurately using the correlation in ESPM (EPRI's ESP predictive model) relating ash resistivity to flue gas temperature and composition. The same correlation did not work well for low temperature hydrated line injection. Further, in the lab, the ash/sorbent mixtures could be conditioned with much smaller amounts of flue gas SO_3 than earlier tests had indicated.
- Particle sizes measurement results were unexpected – the average of the particle size distribution decreases slightly as the rate of lime injection increased, while the percentage of particles less that 1□m in diameter decreased.

These results suggest the lime/reaction product mixture has a much narrower particle size distribution than the ash. Analysis of these results continues and plans are being developed to verify these results in the field, where residence time may alter the findings. For more information, contact Ralph Altman (raltman@epri.com, 423-899-0072).

Continuous Emissions Monitoring (Program 77)

Progress continues on calibrators for mercury CEMS.

The installed calibrators in the field test program were generally stable and able to identify impending malfunctions.

EPRI has completed the data-gathering phase of this effort to evaluate calibrator devices for mercury continuous emission monitors (CEMs). Preliminary evaluation of the data obtained to date indicates that the protocols easily identified the onset of calibrator malfunction. Further, the installed calibrators were found to remain very stable over the evaluation period (except those where malfunctions occurred), with typical values repeatable within 3% in the field bracketing experiments. EPA has completed the elemental calibrator protocols, and is preparing the final version for public comment based on the comments received from the project team. The oxidized calibrator protocols are still not final and cannot be implemented as first drafted. For more information, contact Chuck Dene (cdene@epri.com, 650-855-2425).

Mercury CEMs field calibrator study completed.

Verified that EPA protocols provide necessary QA; suggested that QA criterion be relaxed at low calibration point.

The study has shown that the proposed EPA protocols do alert operators to calibrator failure. Generally, the calibrators performed very well and remained stable over the period tested. Repeated tests indicate that the QA criterion at the low calibration point should be relaxed. The criterion that the relative standard deviation (RSD) be < 0.1% is acceptable for the medium and high calibration points but too difficult for the low point. Relaxation to 0.2% for the low point would not change the accuracy noticeably, as the points most often used for calibration are at the upper level. However, this finding does point out the need to improve the performance of calibrators at the low end for future monitoring requirements. For more information, contact Chuck Dene (cdene@epri.com, 650-855-2425).

Coal Combustion Product Use (Program 78)

Tests characterizing engineering properties of coal combustion products from spray dryer installations.

Results will help identify technologically-viable uses of this material.

Samples of spray dryer absorber (SDA) solid products have been received by the laboratory from eight power plants, and seven of these have already been tested for both physical/chemical properties and engineering characteristics. The property tests include as-received moisture content; elemental, compound and oxide analysis; specific gravity, LOI, available alkali, and SEM micrographs. Engineering characteristics being measured include pozzolanic activity, activity with cement at both 7 and 28 days, and water requirements.

In addition, EPRI is measuring the effects of two activators on the compressive strength of the mortar containing the SDA samples. This testing will evaluate the change in compressive strength (with or without activators) at both 7 and 28 days. A draft interim report incorporating all of the data and the conclusions to be drawn from those data about suitable uses for this material is available. For more information, contact Ken Ladwig (keladwig@epri.com, 262-754-2744).

Tests determining usability of fly ash in concrete from plants using sodium sorbents for SOx control.

Several of the samples tested meet ASTM C618 standards and pass the strength tests.

Fly ash/sorbent mix samples were collected from 16 sites using sodium-based sorbents for SOx control – six for SO_2 and ten for SO_3. All of the SO_2 control samples were from power plants burning subbituminous coal,

while the SO_3 control samples came from plants firing eastern bituminous coals. The samples from SO_2 control applications are categorized as dry sodium-based FGD materials, and those from SO_3 reduction uses are categorized as fly ash due to their very small sorbent/ash ratio.

Testing, which is partially completed, includes major engineering properties and ASTM C618 concrete testing. For the SO_3 control fly ash, the bulk chemical compositions satisfy the ASTM C618 requirements for Class F materials. Further, most samples had an available alkali content below the maximum of 1.50% as Na_2O. Nevertheless, as expected, sorbent addition for either SO_2 or SO_3 control did increase available alkali content compared to the baseline. The ASTM Standard C 618 results indicate that several of the CCPs do meet specifications for use as a partial cement replacement in concrete. In addition, most of the samples passed the 7-day or 28-day strength activity index requirement of 75%., but several did not. An interim report was published in March. For more information, contact Ken Ladwig (keladwig@epri.com, 262-754-2744).

COMBUSTION TURBINES

Combustion Turbine and Combined-Cycle O&M (Program 79)

Guide to compressor blading field repairs in development.

FA compressor is initial focus.

It is relatively common for gas turbine compressor blading to experience denting, cracks or tip damage from foreign object damage, erosion and rubbing. Typically, replacement components are not readily available or outage time is limited and the plant is required to blend or cutback the damaged area to continue operations. EPRI currently is developing a procedure to guide field repairs of damage sustained on components forming the compressor gas path.

Using a customized library of detailed blade and stator models, common repair approaches such as tip cropping or blended removal of material from the airfoil edge can be evaluated. The consequences of altering the blade geometry are reported as changes in stress and frequencies, relative to the undamaged component. The margin of difference is used to assess the potential risk of adopting the repair until the component can be replaced. The initial work is focused on the FA compressor with plans to extend across a range of commonly used gas turbines. For more information, contact John Scheibel (jscheibe@epri.com, 650-855-2850).

Advanced combustion dynamics analysis for gas turbines seeking demonstration sites.

Automated algorithms can provide early warnings about engine health.

Dry low-NOx combustion systems involve difficult tradeoffs between NOx, blowoff, dynamics, and flashback. Feedback between acoustic waves and heat release oscillations may lead to oscillations that damage liners, transition pieces, and connecting tubes. Existing combustion dynamics systems used to monitor acoustic pressure levels can alert operators if amplitude exceeds certain threshold. However, there is a great deal of additional information in the pressure signal ignored which could be used to provide further insight into engine health. Engine hot section health problems often are reflected as changes in engines baseline acoustic signature well before a problem manifests as an alarm. Expert users have used this approach to catch problems before they are catastrophic. Without such expert oversight, current monitors lack sufficient built in intelligence to much in the way of early warning.

EPRI has developed automated algorithms for detecting changes in acoustic signature indicative of anomalies to transition from reactive, threshold based analysis to proactive, signature based analysis. Results obtained to date are very promising; data from several sites which experienced failures has led to detection of anomalous behavior many hours or days before the engine tripped. For example, anomalous behavior in intermediate frequency dynamics (IFD) is detected more than a day ahead of a transition piece failure, and anomalous behavior in low frequency dynamics (LFD) is detected more than a week prior to a pilot nozzle failure. In 2008, the algorithm was extensively tested on sites during “normal” operation to check performance. False alarms were shown to be minimized and data evaluated in blind test was able to identify a pilot nozzle failure well before the occurrence.

This development now is ready for field application. The algorithm needs to be integrated into existing dynamics monitoring system software or plant monitoring software. Results recently were presented to the SW 501F owners group, resulting in five candidate plant sites willing to participate in a longer term evaluation. For more information about this field demonstration plant group, contact Lenny Angello (langello@epri.com, 650-855-7939).

New Combustion Turbine/Combined-Cycle Design, Repowering & Risk Mitigation (Program 80)

Report helps utilities understand characteristics, manufacture of superalloy hot-section components.

All major OEMs offer superalloy components in their highest turbine inlet temperature models; the cost of a first-stage directionally solidified or single-crystal F-class engine blade can exceed the price of gold on a per pound basis, and a significant factor in this overall cost is the specialized manufacturing process. Furthermore, there is a general misconception that these components cannot be repaired.

As part of EPRI's efforts to help power companies better understand current and emerging CTCC technology and make more informed investment decisions, Program 80 published two issues of the *CT Experience and Intelligence Report (CTEIR)* newsletter in 2008 on the characteristics and manufacture of superalloy hot-section components of industrial gas turbines (IGTs). These issues have been combined in a single report, entitled *Combustion Turbine Experience and Intelligence Report: 2008* (1015792).

The January 2008 issue of CTEIR provides an overview of single-crystal (SX) blades. The article includes information on material properties, first- and second-generation alloys, materials processing and recrystallization, current IGT applications, in-service degradation, and repair considerations. The November 2008 issue of CTEIR provides a summary of hot section airfoil manufacturing, with a particular focus on the investment casting process and the unique contributions that advances in the casting process have made to achieving increases in turbine firing temperature and thermal efficiency. The level of technology for producing EA, DS, and SX is reviewed, as well as cored versus non-cored casing for the internal cooling features. For more information, contact John Scheibel (jscheibe@epri.com, 650-855-2850).

Products for improving operational flexibility of gas turbines highlighted in report.

A recent survey detailed products offered by the gas turbine manufacturers to improve the operating capabilities of their engines. Offerings include both hardware and control modifications intended to address the dispatch needs of new and existing plants and make the most of users' generating assets in today's electricity marketplace. Upgrade offerings include products that extend the load range of the units, improve emissions profiles, improve startup time for simple-cycle and combined-cycle units, extend maintenance intervals through improved durability of components, and improve the range of fuel characteristics that can be reliably fired. The survey results and product descriptions are compiled in *Gas Turbine Upgrades for Enhancing Operational Flexibility* (1018522). For more information, contact Dale Grace (dgrace@epri.com, 650-855-2527).

RENEWABLES

Renewable Generation (Program 84)

Overview, final report of the DOE-EPRI wind turbine performance R&D available.

The report, *U.S. Department of Energy/Electric Power Research Institute (EPRI) Utility Wind Turbine Verification Program* (1014488), details the field experience gained by the eight host utilities and numerous partners that participated in the program, the goal of which was to provide a bridge from development to commercial sales of advanced turbines; gain experience with the utility purchase and operation of new wind turbine technology; and communicate the experience to other members of the utility and wind community. The program provided valuable experience and the basis for several of the utilities to develop additional wind projects. It also helped the participating turbine manufacturers test new commercial turbine designs under field conditions and provided the basis to develop new turbine designs for the future. For more information, contact Chuck McGowin (cmcgowin@epri.com, 650-855-2445).

GENERATION PLANNING

Understanding Power and Fuel Markets and Generation Response (Program 67)

Seminar provides insight into expected U.S. gas market transformation.

The recent EPRI-EEI Annual Power & Fuel Supply Seminar included an informative review of what available data can say about the growth of gas shales' production out to about 2012. The investigator said a conservative estimate is about 10 billion cubic feet per day from the top four shales, whereas others see as much as 15 Bcf/d. This will remain one of the most dynamic parts of the U.S. gas outlook, with continuing questions about the interplay of continuing development in a growing number of potentially very prolific shale districts, vulnerability of U.S. production to cycles in drilling, particularly under softening prices, and trends in U.S. gas use, weighing such factors as the recession and U.S. CO_2 policy. Natural gas fired generation is expected to benefit from lower market prices, increasing the financial hurdles faced by coal, coal with CCS, nuclear, and renewable generation. For more information, contact Jeremy Platt (jplatt@epri.com, 650-855-2628).

Technology-Based Business Planning Information and Services (Program 9)

Report provides information on cost and performance of eight key electricity supply technologies.

With aging infrastructure, the emergence of climate change as a new element of a changing regulatory environment, and economic volatility, it is important to present credible information in the public domain on electricity supply technologies. *Program on Technology Innovation: Integrated Generation Technology Options* (1018329) provides an objective, up-to-date publicly available overview of the technical status, performance, costs, and markets for eight central electricity generation supply technologies (>50 MW). The report is based on EPRI's industry standard Technical Assessment Guide (TAG®), and is intended to serve as a high-level information document on technologies that are currently in "play" in the industry. Its publication responds to requests from a diverse range of stakeholders to disseminate the TAG® information more widely.

While the full version of the TAG® addresses about 20 different power generation and storage technologies, this report focuses on eight key central station technologies that are very likely to dominate the future U.S. generation mix over the coming decades. The technologies are: pulverized coal, integrated coal gasification combined cycle, fluidized bed combustion, combustion turbine combined cycle, nuclear, wind turbine, solar thermal, and biomass. The information provides a concise, executive-level overview of near-term (5-10 years) and longer-term (up to 2025) emerging technology costs and performance. The report also provides a thorough basis for its estimates, with detailed information on uncertainty of cost and technical data, accuracy ranges, and current versus constant dollar analysis. As a result, utilities can use the information to assist in the planning process and in interactions with stakeholders, regulators, and public advisory groups.

The changes in market conditions in the third quarter of 2008, which dampened cost escalation, were noted in this report, but the impact of the changes was not incorporated due to lack of data. A separate EPRI report, *Cost Escalation Impact on Power Plant New Capacity Additions* (1018359) provides a full discussion of the cost escalation. For more information, contact Ram Ramachandran (gramacha@epri.com, 650-855-2722).

OUTREACH ACTIVITIES

EPRI Participation at Edison Electric Institute (EEI) Meetings – EPRI's John Novak participated in the December meetings of the EEI CO_2 Capture and Storage Working Group, the Global Climate Change Subcommittee, the Clean Air Strategy Group, and the Environment Executive Advisory Committee (EEAC) held in Washington, DC. His presentation to the EEAC included an update on the following EPRI activities:

- *EPRI Energy Sustainability Interest Group (1016369)*
- *Advanced Coal Power Systems with CO_2 Capture: EPRI's CoalFleet for Tomorrow Vision – A Summary of Technology Status and Research, Development, and Demonstrations (1016877)*
- *Integrated Generation Technology Options (1018329)*

- *The Power to Reduce CO_2 Emissions: the Full Portfolio – 2008 Economic Sensitivity Studies*
- *Corporate PRISM Analysis/CO_2.0 Compliance Optimization 2.0*

EPRI Participation in International Climate Meetings – Novak attended the fourteenth session of the Conference of the Parties to the United Nations Climate Change Convention (COP 14) and the fourth meeting of the Parties to the Kyoto Protocol. The sessions included meetings of the subsidiary bodies to the United Nations Framework Convention on Climate Change and the meetings of the ad hoc groups on the Kyoto Protocol and on long-term cooperative agreements. During the sessions, he provided briefings to key delegates and participants on *The Power to Reduce CO_2 Emissions: the Full Portfolio*, including the *2008 Economic Sensitivity Studies*, on the major demonstration projects, and on CO_2 capture and storage.

National Governors Association (NGA) Carbon Capture and Storage Policy Study Group – Novak participated in a meeting of the NGA Carbon Capture and Storage Policy Study Group at NGA's offices in Washington, DC. His presentation provided states with an overview of 'state of the art' technologies for advanced coal projects and CCS in the U.S. Representatives from Indiana, Illinois, Pennsylvania, Wyoming, Washington, West Virginia, Kentucky, New Mexico, Ohio, and Colorado attended the meeting.

Center for the Study of the Presidency – On Jan. 13, Novak participated in a meeting of the Domestic Energy Production Working Group held by the Center for the Study of the Presidency, a non-partisan, non-profit organization founded in 1965 to promote leadership in the Presidency and the Congress to generate innovative solutions to current national challenges. The Center is the only organization that systematically examines past successes and failures of the Presidency and relates its findings to present challenges and opportunities.

International Electricity Partnership (IEP) – Electric industry leaders representing utilities providing the majority of the world's electricity met in Atlanta, Georgia in 2008 and agreed to form an International Electricity Partnership to deliver advanced electric technologies to create a global low-carbon future. On Jan. 23, Novak participated in a meeting with representatives from international associations and companies to discuss efforts to develop a roadmap for decarbonizing the electric power sector by the year 2050.

U.S. Chamber of Commerce – Barbara Tyran and Novak met with representatives of the Chamber's Institute for 21st Century Energy to discuss potential opportunities for future joint activities.

Solar Energy Industries Association (SEIA) –Tyran and Novak met with Rhone Resch, president of SEIA, to learn about SEIA's membership and activities and to explore opportunities for coordination and collaboration on solar energy.
