WINTER 2008

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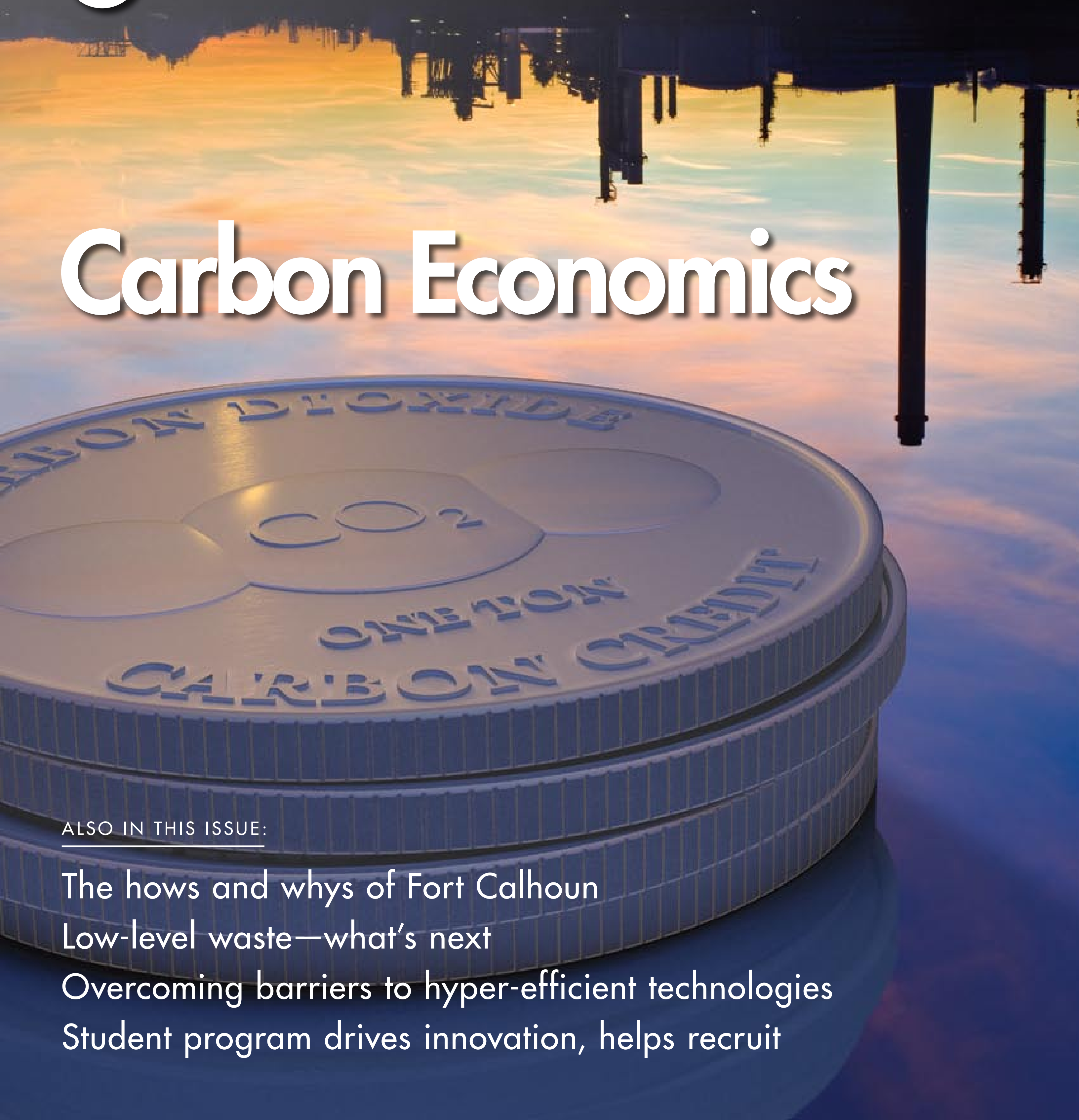

Carbon Economics

ALSO IN THIS ISSUE:

The hows and whys of Fort Calhoun

Low-level waste—what's next

Overcoming barriers to hyper-efficient technologies

Student program drives innovation, helps recruit

The Electric Power Research Institute, Inc. (EPRI) conducts research and development for the global electricity sector. An independent, nonprofit organization, EPRI brings together experts from academia and industry as well as its own scientists and engineers to help address challenges in electricity generation, delivery, and use, including health, safety, and the environment. EPRI also provides technology, policy, and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI's members represent more than 90% of the electricity generated and delivered in the United States, and international participation extends to 40 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

Together . . . Shaping the Future of Electricity®

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WINTER 2008

VIEWPOINT

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DEPARTMENTS

VIEWPOINT

by Steve Specker, President and CEO, EPRI

A Framework for Action

EPRI's collaborative model and overall mission are best described by the phrase "Together…Shaping the Future of Electricity." For at least the next decade, the shaping will almost certainly be defined by our role in helping accelerate the development, demonstration, and deployment of a full portfolio of reliable, affordable, and environmentally responsible low-carbon electricity technologies. EPRI's PRISM has provided a useful analysis framework to guide us in this role. As we translate our analysis into actions, it is helpful to define a corresponding *action framework* to give clarity and focus across the breadth of our research, development, and demonstration activities. This action framework has two key technology elements:

- becoming more energy efficient
- implementing a low-carbon electricity infrastructure

Becoming more energy efficient requires the deployment of technologies across the entire range of end-to-end efficiency opportunities—from generation, through transmission and distribution, to end-use. While some of these technologies will be integrated into the evolving low-carbon infrastructure, others, such as more-efficient end-use devices, can be implemented in the near term without infrastructure investments. These near-term opportunities are often described as "low-hanging fruit." Unfortunately, it too often seems that this low-hanging fruit is enclosed by a barbed-wire fence and is hard to get at. On page 14, we discuss our actions to cut through the barbed wire that is impeding the introduction of hyper-efficient end-use technologies into the U.S. market.

Implementing a low-carbon infrastructure can be thought of as the merging of four evolving infrastructures:

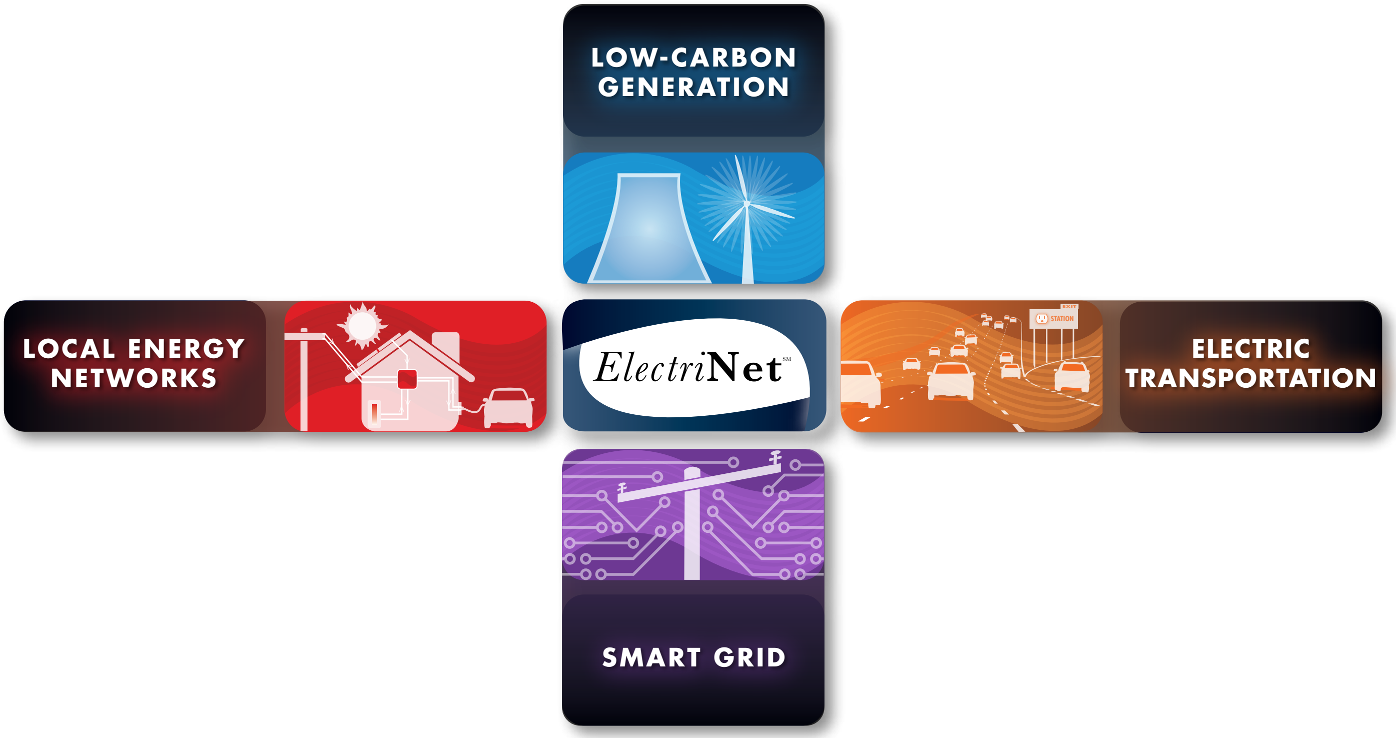
- low-carbon generation
- smart grids
- local energy networks
- electric transportation

Over the coming decades, these four infrastructures will come together to form what we are calling the ElectriNet℠. Whereas *the grid* defined the electricity system of the twentieth century, we expect that *the ElectriNet℠* will come to define the intelligent, low-carbon electricity system of the twenty-first century.

At EPRI we are helping shape the ElectriNet℠ through a range of programs to accelerate the implementation of technologies that enable the four infrastructures. We are also developing standards and open information architectures that will enable the merging of these infrastructures into the ElectriNet℠.

While most readers are familiar with low-carbon generation technologies (renewables, nuclear, and fossil with carbon capture and storage) and smart-grid technologies (two-way communications, advanced sensors, and distributed computing), the inclusion of local energy networks and electric transportation is worthy of some additional discussion.

Local energy network is the term EPRI has adopted to describe a home, building, or small community that is grid connected and also has its own capability to generate electricity and/or store energy. Local energy networks are not new. Many industrial facilities with on-site generation and grid connectivity already manage their energy with sophisticated energy management systems. What is new is the proliferation of local energy networks to homes and commercial buildings, which is occurring as distributed generation such as solar photovoltaics is installed. This proliferation will accelerate as the smart grid enables dynamic pricing, as electric vehicles begin plugging in, and as smart, hyper-efficient appliances become more available. As they merge, smart grids and local energy networks become the information network of the ElectriNet℠, making it possible to optimize the utilization of electricity, from the end-use device to the overall utility system.



The electrification of substantial portions of the world's transportation infrastructure is not merely an option: it is required, along with low-carbon electricity generation, if there is to be any chance of eventually stabilizing atmospheric CO_2 anywhere near the levels recommended by the scientific community as necessary to limit global temperature increases. For this reason, electric transportation is, and must continue to be, one of our most important and urgent programs. In the past year, we have announced key collaborative projects with General Motors and Ford Motor Company to facilitate the integration of plug-in hybrid electric vehicles into today's grid.

As an action framework, ElectriNet[SM] is providing clarity and focus to EPRI's research, development, and demonstration programs. I hope that you will also find it useful in thinking about the role of electricity technologies in creating a low-carbon future.

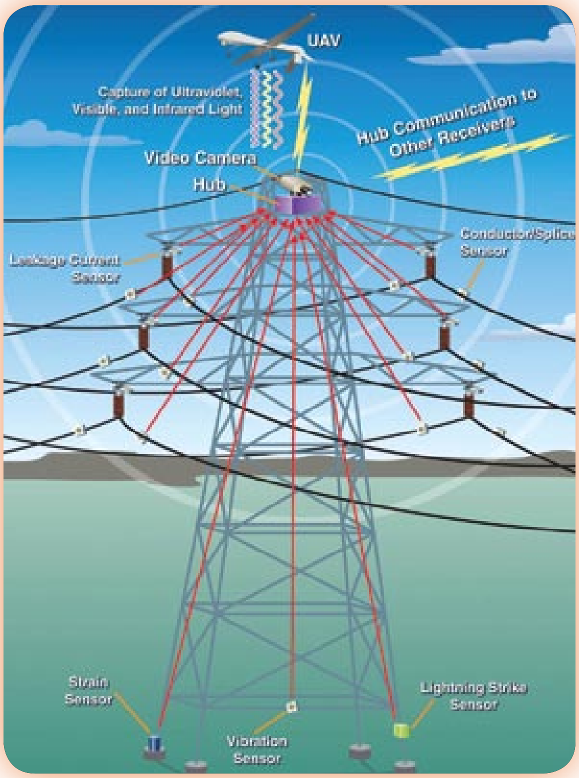
Steve Specker
President and Chief Executive Officer

SHAPING THE FUTURE

Innovative approaches to upcoming challenges

Transmission Line Assessments for the Twenty-First Century

As the nation's transmission system gets older and requirements for system reliability increase, assessments of overhead lines will require more-detailed information—from below the ground to the tops of transmission structures—if the failure of aging components is to be avoided. The general condition assessments typically done with an airplane or helicopter flyby will not be sufficient to meet this greater need, and closer examinations currently require maintenance personnel to drive the circuit, perform detailed visual inspections, and take actual measurements on the towers or from hydraulically raised inspection platforms—a very labor-intensive proposition.



In the future, inspections may be performed automatically, in far greater detail, and in many fewer work-hours, thanks to a confluence of cutting-edge techniques involving advanced sensors, GPS satellites, wireless networks, and even robotic devices.

The assessment system being developed centers around an instrumented transmission structure that could include sensors to detect structural strains, line surges, leakage currents, and other mechanical/electrical variables, as well as specific events like lightning strikes and vandalism. Sensor technologies range from the conventional—video cameras, microphones, vibration transducers, and strain gauges—to the newest micro-electromechanical accelerometers and magnetostrictive sensors.

One option for collecting data from these sensors employs a data hub, installed on the same or a nearby structure, that receives the information and transmits it to the utility's centralized data management system via a wireless communication system such as a radio-frequency, satellite, or Wi-Fi network. As an alternative, the sensor data may be collected by flyby aircraft, by unmanned "drone" planes like those used in defense surveillance activities, or even by robots that crawl along the wires. These vehicles may have their own automated sensors, such as laser-based detection systems and visual, infrared, and ultraviolet cameras. Receivers mounted inside utility trucks may also collect data automatically as the maintenance worker drives along the circuit. In all these cases, the data hub and telecommunication links significantly increase the amount of highly detailed information that can be gathered and vastly reduce the time and effort required to retrieve it.

There are no serious barriers to the basic instrumented tower concept, but a number of practical issues will need to be addressed. One challenge is the vast amount of information generated by such a system. To reduce the huge volume of data on central servers, sensors may be designed to operate in an alarm mode—reporting only when they detect high-risk conditions. Detailed information can then be downloaded to the server for further analysis.

In addition, sensors and communication hubs will require power for operation. While batteries would provide a convenient option for testing and demonstrating the new system, they would also require periodic replacement or recharging, weakening the low-maintenance, automated aspect of the system.

One potential alternative is a power harvesting device, which captures untapped wind, solar, thermoelectric, or kinetic energy from the ambient environment or energy from the lines' own magnetic fields. Some self-sustained power devices may be decades from practical application, but they represent promising alternatives for a fully automated line monitoring system.

A pilot demonstration of the instrumented tower concept will be carried out by EPRI and FirstEnergy of Akron, Ohio, in 2009. The pilot's single tower will carry a number of sensors of various types and a fixed data-collection hub that can test at least two different communication techniques. The sensors being deployed include splice/conductor temperature sensors, insulator leakage-current sensors, vibration sensors, and two smart cameras mounted on the tower to provide a visual record of activities such as right-of-way encroachment and conductor galloping.

All of the pilot's sensors will be monitored in real time as an alarm for simulated catastrophic conditions, such as system

outages; sensors can also be polled at intervals appropriate for detecting the gradual condition degradation typical in power transmission components. This instrumentation is expected to support several test scenarios that will demonstrate a variety of system features and benefits. Successful development of an integrated, automatic assessment and monitoring system could greatly increase the efficiency, reliability, safety, and security of electric power transmission.

For more information, contact Andrew Phillips, aphillip@epri.com, 704.595.2234.

Regional Water Quality Trading

Trading of emissions allowances proved to be a successful strategy in the battle against acid rain and is now being strongly considered as an economical approach to controlling CO_2 emissions. EPRI analyses have shown that regional allowance trading, when used in conjunction with traditional command-and-control approaches, may also be valuable for dealing with power plant water discharges. Under this system, a permitted discharger facing high costs to accommodate new growth or to meet more-stringent effluent limits could “trade” for discharge reduction credits generated by another source having lower costs—for example, an agricultural producer implementing conservation practices. A portion of the reductions traded could be retired to address uncertainty or to create a net reduction of pollutants such as nitrogen, phosphorus, and sediments discharged to the receiving water.

The recently completed EPRI study analyzed the feasibility of multistate water quality trading in the Ohio River basin. This effort resulted in a strong business case for the participation of coal-fired power plants in such a program, especially for the management of nitrogen discharges associated with the more-restrictive wastewater discharge permit limits expected with forthcoming instream nitrogen standards. In fact, EPRI’s research indicates that new efforts to control air emissions may actually lead to nutrient water discharges and effluent compliance problems.

Under current regulatory conditions, the only option power companies on the main stem of the Ohio River have for complying with stricter water discharge limits will be investment in on-site treatment capacity. Similar constraints exist for publicly owned treatment works (POTWs) facing both nitrogen and phosphorus limitations with pending nutrient standards. Water quality trading offers a cost-effective alternative, under which purchased discharge offsets would partially achieve the water quality permit compliance required under the National Pollutant Discharge Elimination System (NPDES).

While water quality trading is not unknown in the United States, efforts have centered around bilateral trades, in-state watershed-based programs, and state-based trading rules. Few, if any, trading programs have attempted trading at a regional or interstate scale, which would assume common goals or regulatory drivers. Meanwhile, existing small-scale trading efforts have resulted in fragmented markets, high transaction costs, expensive program development, and limited trades—constraints that have hindered interest in crossing geopolitical boundaries.

According to the EPRI feasibility study, the Ohio River offers a good opportunity for developing a regional trading framework: the region is characterized by robust and diverse stakeholder interest and a willingness to participate in regional trading program development. High demand for water quality trading credits is anticipated from several sectors of NPDES dischargers, including both power companies and POTWs. An ample supply of low-cost credits from agriculture appears achievable. Past success at the local scale in the Ohio River basin (i.e., the Great Miami River trading program) supports opportunities to move forward with regional trading, as most of the traditional roadblocks have been overcome. Regulatory agencies have shown interest in the regional trading approach, and an interstate coalition of stakeholders in the Ohio River basin is now forming to pursue its development.

Success of the program will require confidence in the ecological outcomes of water quality trades—confidence based on evaluation of potential trades among various sources, analysis of how different trading zones will affect results, and tracking of progress toward achievement of nutrient reduction goals. EPRI’s Watershed Risk Management Framework model, or WARMF, a publicly available watershed-scale water quality model developed for two watersheds in the Ohio River basin, will be extended to provide such information for the entire basin. The model will provide an ecological basis for structuring the trading program: avoiding hot spots, assessing potential trading partners, and establishing credit ratios. The model will also support an adaptive management strategy, as revised model predictions over time will provide additional information to decision makers and program participants.

The next steps toward developing and instituting a viable trading program in the Ohio River basin will include two primary efforts: verification of the need for trading through a broader regional analysis of supply and demand in the basin, focusing on both nitrogen and phosphorus; and engagement of high-level regional, state, and selected local participants to identify and secure support at the buyer, seller, and regulator levels.

For more information, contact Jessica Fox, jfox@epri.com, 650.855.2138.

CLIMATE POLICY

The Cost of Compliance

THE STORY IN BRIEF

The electric power sector will have a major role to play in helping to reduce greenhouse gas emissions. The cost may be quite high, and depending on the structure of the reduction program, many utilities could face a significant gap between achievable emission levels and the emission permits they are given—a gap that would have to be filled by buying allowances in potentially volatile markets. EPRI analysis provides insights into how different costs for reducing emissions may drive electricity price increases and how utilities could shift operational and investment strategies in response.

How expensive will it be for utilities and their customers to make the transition to a low-carbon future? How and when utilities reduce emissions will profoundly affect the answers to the question, "How much will it cost?" Evaluating the range of approaches available can help the electricity sector choose the best near-term and long-term options for complying with anticipated mandatory reductions.

Electricity generation accounts for about 39% of total CO_2 emissions in the United States, with more than four-fifths of these emissions coming from coal-fired power plants. In the near term, electric utilities have limited options for achieving the needed reductions. Primarily, they can run gas-fired power plants more of the time rather than dispatching coal-fired plants, which have lower costs but higher emissions. Over the long term, more generation alternatives will become available for reducing emissions, but introducing new low- and non-emitting technologies will be an expensive process. As a result, climate policies aimed at reducing CO_2 emissions will create severe compliance challenges for the electric power industry. And in any case, utility customers can expect significant rate increases and perhaps some sudden price shocks.

Figuring out just how expensive the transition to a lower-carbon future may be is quite difficult. Nearly two dozen scenarios have been published that estimate the potential economic effects of the Lieberman-Warner Climate Security Act of 2007, for example, with the various results spread out over an eightfold range in terms of the projected cost in 2030. With regard to the electric power sector, most studies have used a top-down approach focused on how constraints on emissions would affect the aggregate cost of generating electricity at various types of power plants. Production costs do not tell the whole story, however. In particular, they do not account for how utilities will adjust to constraints by shifting between existing coal-fired and gas-fired plants or how investments in new plants are likely to change the generation mix. Also, almost no attention has been paid to the critical issue of trading emission allowances, which will be relied on by many utilities that cannot meet required targets through physical abatement activities.

To address some of these outstanding issues, EPRI conducted a series of bottom-up analyses of the electric power industry that focus on such mechanisms as fuel substitution, future investment, and emissions trading. Rather than attempting to predict how the coming transition will play out, the analyses provide utilities with insight into how emissions production would respond to various CO_2 emission costs, and perspective on the impact of those costs on electricity prices. Key regional differences are also considered.

"Electric utilities need better information about how national emission constraints are going to affect their operations and planning," said Victor Niemeyer, who oversees the ongoing analysis effort. "The bottom line is that the electric power sector has the potential to cut CO_2 emissions substantially, but the cost will be much higher than some previous studies have indicated, particularly if near-term cuts are required. Compliance with climate policy will also force utilities to juggle participation in volatile emission-allowance markets with long-term planning for various emission-abatement activities."

Cost of Redispatch

An immediate strategy to reduce emissions from the existing generation fleet is to redispatch gas-fired plants in preference to coal-fired plants. How much would it cost? Consider the case of two power stations connected to the same regional transmission system. The coal plant in this example emits 1.2 tons of CO_2 per megawatt-hour (t/MWh) and has a variable operating cost (fuel, ongoing maintenance, etc.) of $16/MWh. The gas-fired combined-cycle plant emits less than half the CO_2—0.5 t/MWh—but operates at a cost of $66/MWh.

With no constraints on CO_2 emissions, the coal plant runs virtually flat out, while the gas plant is dispatched slightly more than half the time, when the regional wholesale electricity price is high enough to justify its use.

If the utility chose to dispatch the gas plant instead of the coal plant in response to climate policy, the additional cost would be $50/MWh ($66/MWh minus $16/MWh), and the reduction in regional CO_2 emissions would be 0.7 t/MWh (1.2 t/MWh minus 0.5 t/MWh). That works out to $71/t—more than double recent CO_2 emission allowance prices on the European Climate Exchange, which have been running closer to $20–$30/t.

This example raises several important issues that need to be considered in greater detail. The first concern is whether the proposed substitution could, in fact, take place. If the gas and coal plants under consideration are widely separated, redispatch might not be possible because of transmission system congestion or might involve significant transmission charges. Also, the cost of redispatch at any given time would depend strongly on the price of natural gas. The example above assumes a gas cost of about $8 per million British thermal units (MMBtu), but prices closer to $10/MMBtu would result in a CO_2 cost of nearly $91/t to make the same gas-for-coal substitution.

Utilities must also account for regional factors, such as the significant differences in the fuel mix of power generation fleets. For example, redispatch would be much easier in regions with numerous gas-fired power plants than in regions dominated by coal. As a result, rising CO_2 prices created by climate policy could produce much greater emissions reductions in a gas-rich area, with the greatest reductions achieved when natural gas prices were low. In coal-dominated regions with limited substitution opportunities, even very high CO_2 prices might produce only small reductions in emissions, and the response would be reduced further when gas prices were high.

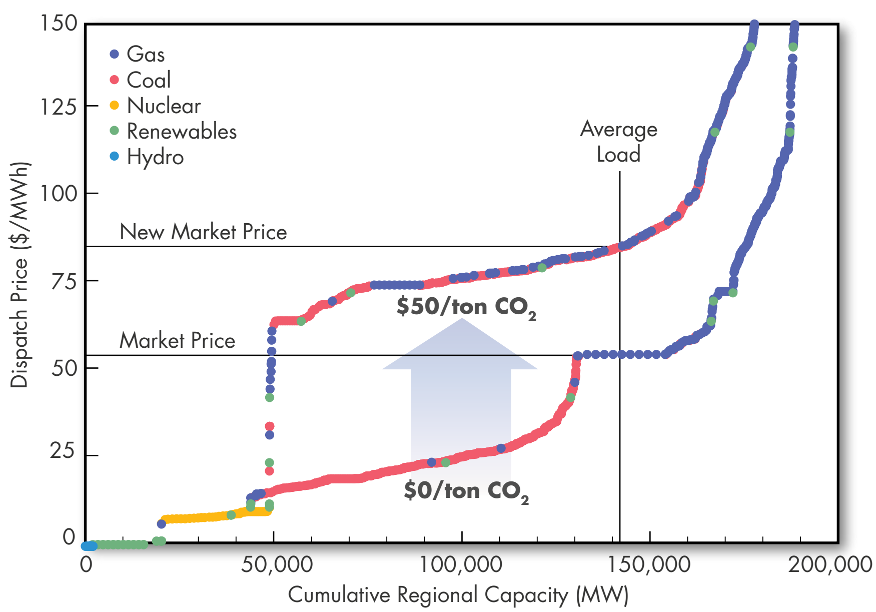
Longer-Term Options

Over the next 20 years or more, new investment could fundamentally change both the electricity generation mix and end-use patterns. EPRI's analysis indicates that customers will respond to climate policy primarily as a result of rate increases. Investment decisions about new generation will depend largely on how emission constraints affect various plant dispatch costs and net revenues on a regional basis.

Within each region, individual power plants are brought on-line according to their relative operating costs. Nuclear and renewable resources are usually dispatched first and run continuously when available. Various coal plants come next, in the order of their efficiency and other cost factors, and often account for more than half of generating capacity. As demand rises during the day, higher-priced gas and oil generators are brought on-line as needed.

The resulting supply curve, which displays the cost and dispatch position for each plant in a power system, tends to have a jump in cost between the nuclear plants at the lower left and the long flat portion represented by coal plants. A steeply rising portion of the curve on the right represents natural gas and oil plants—some of which may be dispatched for only a few hours each year to meet highest peak demand. For each hour during a year, the marginal cost of the last plant to be dispatched sets the wholesale market price for the regional power system.

The net revenue earned by a particular plant in a given hour is the difference between its operating cost and the market price. For example, if the last gas plant dispatched sets a marginal price of $80/MWh—its break-even point—then a coal plant operating at the same time at a cost of $16/MWh would earn $64/MWh in net revenue. Such revenue variability can profoundly affect the choice of new generation, particularly if the cost of carbon emissions sharply raises the marginal price of dispatching coal plants. Nuclear plants and renewable generation would remain unaffected by such an emission penalty, while gas plants would be less affected than coal plants because they emit only about half as much CO_2 per megawatt-hour.



Emergence of a pricing structure for CO_2 emissions will not only raise the overall price of electricity but also tend to change the order of dispatch for power plants. At a CO_2 price of $50/ton, lower-carbon-emitting gas plants will be dispatched before many coal-fired units. The market price is set by the last plant dispatched to meet load.

Regional Impacts

To determine how these factors play out in actual power systems, EPRI conducted detailed analyses of the impact that CO_2 constraints would have on the regions under the management of the Midwest Independent System Operator (MISO) and the Western Electricity Coordinating Council (WECC), respectively. These two regions have some significant differences: MISO relies more on coal and has a higher rate of load growth and lower electricity rates. Both systems were analyzed in terms of how a range of constant CO_2 price scenarios beginning in 2012 would affect generation investment, plant operation, emissions, fuel use, and power prices out to 2030.

A major conclusion of these analyses is that stabilizing electricity sector emissions at close to present levels in both regions would require a CO_2 price of approximately $50/t and that cutting emissions in half by 2030 would require a CO_2 price of approximately $80/t. In addition, a price of $100/t or more would be needed to reduce emissions in the initial program years, partly through gas-for-coal substitution but mainly through decreased customer demand driven by punishingly high electricity prices.

Other results provide insights into how the generation mix in the MISO region might change, assuming two different CO_2 prices. With CO_2 at $50/t, generation output from coal would steadily decrease, initially as demand dropped and gas plants were used more extensively; by 2030, new nuclear and renewable resources would play a larger role, and more-efficient end-use technologies would greatly expand opportunities for demand reduction. If CO_2 were priced at $85/t, the phaseout of coal would be greatly accelerated in favor of faster growth for new gas and nuclear plants.

Electricity prices would rise rapidly and sometimes suddenly in both regions. In MISO, for example, imposing a $50/t cost for CO_2 emissions in 2012 would cause wholesale electricity prices to jump from about $60/MWh to more than $100/MWh, where they would remain through at least 2030. WECC would see a somewhat smaller price increase in percentage terms, partly because of greater opportunities for initial coal-to-gas shifting and because power prices start out at a higher level in WECC because of greater use of gas in that region.

Critical Role of Allowances

Given the potentially large impacts of climate policy on power system operations and electricity prices—particularly if proposed near-term emissions reductions are enacted—electric utilities are unlikely to be able to meet emission targets on their own. As an alternative to imposing a carbon tax directly, most proposed climate legislation has instead provided for a cap-and-trade system of emission allowances, which would set a market price for CO_2. Since no mandatory emissions reductions have yet been established, however, the future role of allowances in utility compliance strategies is uncertain.

One key issue is whether utilities will initially be provided with no-cost allowances to help in the transition. EPRI studies of the potential effects on rate-regulated utilities in WECC indicate that complying with CO_2 emission constraints at $75/t would result in a $33/MWh wholesale price increase for electricity, assuming utilities had to purchase all the allowances they needed. This increase would drop to less than $20/MWh if half the allowances were provided at no cost and these savings were passed on to the customers. Both figures include a price increase of approximately $5/MWh resulting from utilities' own emission-abatement activities, such as fuel substitution.

Another major question is whether utilities will be able to pursue carbon offsets—such as reforestation projects—in order to comply with required emissions reductions. Various options exist domestically and internationally for offsets, and their availability could sharply reduce the electricity sector's compliance burden. New projects take time to arrange, however, and stringent rules such as those currently in force in Europe could limit the usefulness of offsets.

Finally, there's the issue of market volatility. The price of emission allowances in Europe fell by roughly two-thirds in just a couple of weeks during 2006, then more than doubled the following week. Meanwhile, in the absence of U.S. emissions mandates, the Chicago Climate Exchange has provided a voluntary, but binding, market for trading allowances. This year, the price of these allowances first rose threefold and then fell to less than half the value they had had at the start of the year.

"It now seems likely that most utilities are going to have to count on emission allowances for a large part of their compliance with climate policies," said Victor Niemeyer. "Physical abatement activities are going to fall short, especially in the near term, which will probably leave a compliance gap representing the bulk of the power industry's required reductions. In that case, only allowances and offsets will enable utilities to fulfill the requirements of most climate legislation now being considered. In light of this reality, utilities need to prepare now to develop effective trading strategies for use in very volatile emissions markets."

This article was written by John Douglas, science and technology writer. Background information was provided by Victor Niemeyer (niemeyer@epri.com).

Victor Niemeyer is manager of EPRI's Greenhouse Gas Reduction Options program, focused primarily on market mechanisms in climate policy design, market impacts of climate policy, and the benefits and risks of new technologies. Before joining the Global Climate Change program, Niemeyer managed the Institute's Power Markets and Risk program area and was also responsible for the grid reliability and security programs. Niemeyer holds a B.A. in economics from the University of California at Berkeley and a Ph.D. in economics from the University of Texas at Austin.

AFTER BARNWELL

The New Realities of Low-Level Waste

In 2000, the South Carolina General Assembly voted to reduce the influx of low-level radioactive waste (LLW) to the state's Barnwell regional disposal facility. As of July 1, 2008, the Barnwell site, once open to all U.S. generators of LLW, accepts shipments only from the three states of the Atlantic Compact: Connecticut, New Jersey, and South Carolina itself. With the Barnwell site's closing affecting about 85% of nuclear facilities in this country, South Carolina's decision carries a considerable impact.

Far less radioactive than fuel-based high-level waste, LLW is essentially process waste. The least radioactive LLW category is Class A, which consists mostly of dry maintenance materials such as cleaning rags, gloves, and protective clothing. Class B and Class C wastes have higher levels of activity and are composed mostly of resin waste and filter media waste. The storage of each of these three classes is prescribed under specific Nuclear Regulatory Commission (NRC) regulations. Until Barnwell was closed to out-of-compact wastes, however, all U.S. generators had access to a disposal path for their Class A, B, and C wastes.

Besides Barnwell, only two other LLW storage facilities operate in the United States today. A facility in Clive, Utah, accepts certain types of Class A waste from all U.S. nuclear plants; the other facility, near Richland, Washington, accepts waste only from the Northwest and Rocky Mountain compacts. With no other options currently available, commercial LLW generators in the 36 states that used to ship their Class B and C waste—about 425 cubic meters per year, or roughly the volume of a small house—to the Barnwell site will now have to store it on site at their own facilities.

How much impact has the Barnwell closing actually had on the nuclear industry? "There had been some talk earlier about the site's closing, but it managed to stay open," said Miguel Azar, corporate radwaste manager for Exelon Corporation. "So some in the industry weren't expecting the closure when it finally did come, and they'll have to accelerate their storage plans." Because the bulk of LLW is Class A—which is disposed of at the Utah facility—rather than Class B or C, the impact on the industry is not as great as it could have been, according to Azar. The industry has done well in managing its LLW and, in general, has reduced the volumes of Class B and C wastes generated since the Barnwell site announced its closure.

Mark Carver, manager of fleet radwaste for Entergy Services, agrees. "The impact on the nuclear power community may be less severe and easier to absorb than the impact on other generators of LLW, such as hospitals, universities, and research facilities that don't have on-site storage facilities," he said. Still, expansion of on-site storage will be a challenge for nuclear utilities, and as Carver pointed out, LLW disposal may become more of a sticking point for future plants: "The issue has a higher level of prominence for some new-build nuclear plants because of the need to demonstrate to the NRC that their Class B and C waste can be managed effectively without an available central disposal site."

THE STORY IN BRIEF

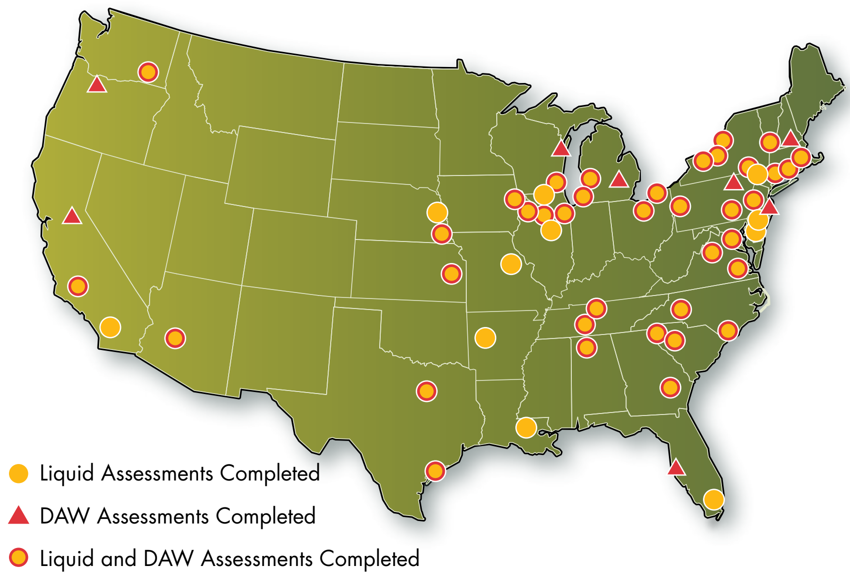
With the nation's main low-level waste disposal facility now closed, the great majority of U.S. nuclear plants have no option but to store some of their low-level waste on site. The closing has brought many aspects of waste management back into sharp focus: the need for on-site storage, an emphasis on volume reduction and improved processing strategies, and a push for regulatory change.

Making On-Site Storage Available

Nuclear plants have safely stored active waste on site for years. Even though each LLW class represents a low level of activity, it must conform to strict storage or disposal requirements: Class A waste must be considered active for 100 years, Class B for 300 years, and Class C for 500 years. The higher the waste classification, the more protection is called for, and—in the case of the Barnwell landfill—the deeper the waste must be buried. Safe, secure on-site storage calls for well-designed, well-built structures that can accommodate LLW for at least 10 to 20 years. Some nuclear plants already have such structures in place, and others, which have been relying on temporary storage facilities, are beginning to build for the longer term.

EPRI began developing a series of guidelines for LLW management and the construction of on-site storage facilities in the early 1990s, when the first intimations surfaced about an eventual closing of the Barnwell site. After the South Carolina legislature formally voted in 2000 to close the Barnwell facility, EPRI revisited and updated those guidelines, which cover a wide range of topics, including the design and construction of on-site storage facilities, the proper storage containers to use, the potential of biological gas developing during storage, and the necessary waste management forms to maintain.

EPRI also developed on-site storage guidelines to help utilities operate their storage facilities in accord with NRC regulations. An industry committee recently updated these guidelines for submittal to the NRC for review. The desired outcome is for the NRC to issue a statement indicating that the operation of on-site storage



EPRI on-site assessments of liquid and dry active waste (DAW) can help utilities manage LLW, lowering both the volume produced and the cost of storage.

facilities according to EPRI's guidelines is consistent with NRC regulations.

Emphasizing Volume Reduction

With the Barnwell site's closing, nuclear plants now face the challenges and corresponding costs of increased maintenance and monitoring of their waste. In fact, those costs could represent a twofold increase over the costs of disposal at the Barnwell site. As a result, nuclear plants are taking a closer look at processes and operational practices that might help lighten the LLW storage burden. The concept of volume reduction has gained renewed traction as a guiding principle, with a particular focus on minimizing waste at the higher classifications (Classes B and C) as much as possible.

Because resins and filters used in liquid treatment processes make up most of the Class B and C waste being generated, such media offer a prime target for volume reduction. As addressed in EPRI's *Waste Class B/C Reduction Guide* (1015115), the use of innovative media such as nonmetal filters is one practice that plants can employ to reduce the volume of Class B and C waste generated and requiring on-site storage. Another option is to use ion exchange for specific radionuclides. Radioactive isotopes such as cesium, for example, are key contributors to a higher Class B or C characterization of demineralizer waste. If operations personnel manage radionuclide-specific media selectively, a plant could theoretically lower its overall volume of Class B and C resin by at least 50% by using new technology and by concentrating key contributor radionuclides on a smaller volume of media.

Changing out resin beds more frequently, before the buildup of filter waste to the Class B or C level, can also be effective; this approach results in a higher volume of Class A waste, but it reduces the volume of the more demanding Class B and C waste, which may not have a current disposal path. Add to those changes the optimization of demineralizer operation, and the reduction in the volume of LLW can prove significant.

EPRI offers a series of on-site assessments to assist utilities in improving LLW management; storage assessments, for example, employ a two-pronged approach to help individual plants address challenges related to on-site storage. First, EPRI reviews the storage facilities and the associated technical documentation and operating procedures to ensure that the facilities are designed and operated in accord with on-site operating guidelines. This step can help a utility gain confidence in its operations, and it identifies any areas where improvements could be made.

Second, EPRI examines the generation of Class B and C waste to help plants identify where operational changes could be made to reduce the volume of that waste being generated. This step helps utilities identify where they can most benefit from Class B and C volume-reduction techniques and how they can reduce the amount of waste that may have to be stored on site.

Pursuing Concentration Averaging

Technical modifications at the regulatory level could also improve LLW management. The NRC developed specifications for safe LLW storage and for classification of the waste itself in the early 1980s. To formulate the storage criteria, the NRC considered the climate, humidity, water table, and other environmental and geological factors for four hypothetical regions of the United States. The agency then chose the most conservative regional value for each of these parameters to represent the overall U.S. storage risk.

But because the risk factors actually differ from region to region, this one-size-fits-all basis for safety margins may be excessively conservative in the final result. The standards appropriate for a disposal site in the northeastern United States, for example, would be overly conservative in the arid climate of Texas. Drawing on analyses carried out cooperatively with the Nuclear Energy Institute (NEI), EPRI is proposing regulatory acceptance of risk-based criteria for waste characterization, which could be established without the need to seek changes to the rules. The NRC has stated it will review this proposal.

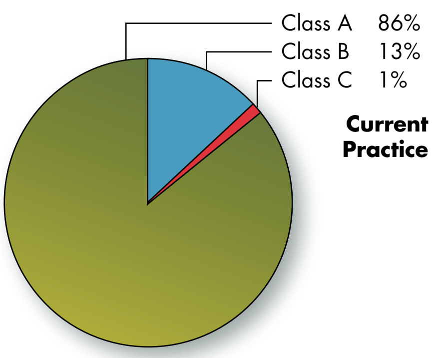
Another restriction comes into play as well: an NRC branch technical position (BTP) that offers guidance on concentration averaging. It seeks to prevent a generator of LLW from combining a distinct, high-activity radioactive source with other

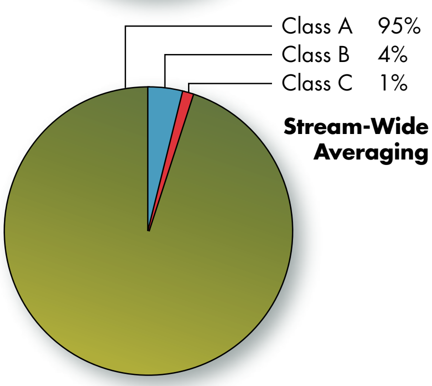
LLW, averaging the high and low activity levels, and calling the resulting package LLW. The BTP prohibits such concentration averaging.

The BTP's broad scope, however, also restricts a generator's ability to average the concentrations of similar LLW wastes—even those from the same waste stream. For example, resin wastes from different parts of a nuclear plant may differ somewhat in their levels of radioactivity, but the utility may not be able to average them under the given constraints. In light of the new strategies discussed earlier for managing waste media, the ability to average LLW concentrations could reduce the amount of Class B and C waste that needs to be stored on site.

EPRI research indicates that a more risk-informed approach to waste classification would allow for the safe and reasonable averaging of similar types of LLW while retaining restrictions on the packaging of discrete, high-activity sources. The NRC has signaled its willingness to revise the BTP, suggesting that the practice of concentration averaging should be allowed more flexibility than it has received so far. "We are very supportive of increased flexibility," said Azar. "We've gained significant knowledge over the years on the safe handling and storage of LLW, and it's time for the controls to reflect what we know today."

Having presented its supporting data to the NRC, and having then answered the agency's questions, EPRI has completed most of its work on waste classification. It plans to publish a final report on the issue by the end of 2008. NEI and the NRC will work together to submit the proposed changes for public review. If and when approved, the revised BTP incorporating concentration averaging would offer some relief in managing low-level waste. "All of these accomplishments represent a strong effort on the part of EPRI, NEI, and the utility industry," said Carver.





Revision of NRC technical guidance on stream-wide LLW averaging could substantially lower the volume of Class B waste that must be stored on site.

Providing Global Guidance

While the Barnwell closing complicates life for nuclear plant operators in the United States, concerns over the management and disposal of low-level waste are equally important globally. EPRI on-site assessments can provide targeted guidance for LLW volume reduction, handling, storage, and disposal. The Spanish utility Iberdrola Generación has been particularly interested in volume reduction, and it engaged EPRI to investigate improvements for LLW management at its 1,085-MW Confrentes power plant in Valencia.

After a week of on-site analysis, the assessment team recommended several near-term actions related to water management and alternative filter technology, as well as longer-term reevaluation of the demineralizer and waste solidification systems. When fully implemented, the proposed changes are expected to result in a reduction of at least 20% in solid waste generation at the plant.

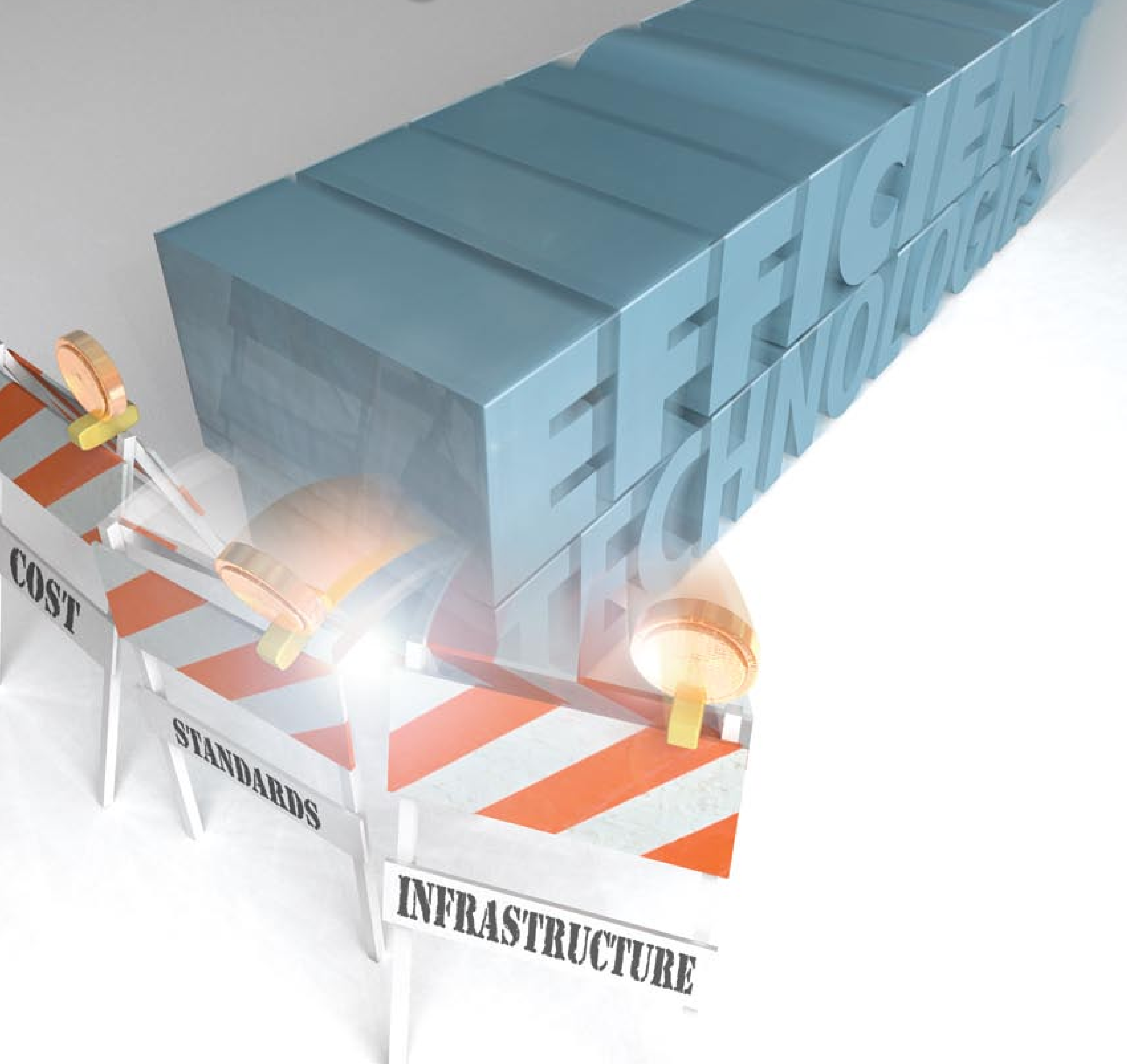
As the Iberdrola work demonstrates, volume reduction is a global issue in nuclear power generation; the means of storage may differ from country to country, but ensuring adequate storage capacity remains a universal challenge that EPRI technical guidelines and assessments can help address. Over the past 15 years, EPRI has conducted comprehensive LLW assessments at more than 100 plants worldwide.

This article was written by Hans VanderKnyff, business and technology writer. Background information was provided by Sean Bushart (sbushart@epri.com) and Lisa Edwards (ledwards@epri.com).

Sean Bushart is program manager for the Low-Level Waste, Chemistry, and Radiation Protection area of the Nuclear Sector. His current activities focus on water quality improvement, waste minimization, environmental protection, and radiation worker safety, and he holds a patent on the EPRI Magnetic Molecules Process for waste minimization. Prior to joining EPRI in 1999, Bushart worked as a laboratory director at CytoCulture Environmental Biotechnology. He holds a B.S. degree in biology and a Ph.D. degree in biology with specialization in contaminant degradation from Rensselaer Polytechnic Institute.

Lisa Edwards is a senior project manager in EPRI's Chemistry, Low-level Waste, and Radiation Management program, where her current activities focus primarily on low-level waste management, assessment, and storage. Before joining EPRI in 2007, Edwards had over 18 years experience in commercial nuclear utilities and was a Training Manager at Cooper Nuclear Station and Plant St. Lucie. She received her U.S. NRC Senior Reactor Operator license for Comanche Peak Units 1 and 2 in 2001. Edwards holds a B.S. degree in Chemistry from Cornell College.

Demonstrations Encourage Wider Use of Efficient Technologies



THE STORY IN BRIEF

Several hyper-efficient electric end-use technologies are now being considered for use in the United States, where for a variety of reasons they are not yet widely used. EPRI and several U.S. utilities are collaborating on a demonstration project to expand understanding of these promising technologies and of the barriers to their deployment in the United States. The ultimate aim is to overcome those barriers to help substantially reduce overall power consumption and carbon emissions.

Of all the ways proposed to reduce the growth of carbon emissions, one of the most cost-effective is to reduce consumer demand for electricity through greater end-use efficiency. It's also one of the potentially quickest solutions—especially considering that a variety of highly efficient new end-use technologies are available and ready for deployment. The problem is that each of these technologies faces specific barriers to broader use in the United States, even though several have already been widely adopted in Europe and Asia.

To help overcome these barriers, EPRI is launching a demonstration project—hosted by multiple utilities—aimed at providing critical information and operating experience related to six promising technologies. These technologies were chosen because of their ability to reduce electricity consumption significantly in some of the largest demand categories—up to 40% in specific applications. Overall, full deployment of the six technologies could reduce U.S. electricity consumption by as much as 7% and reduce carbon emissions by more than 160 million tons per year—the equivalent of taking 30 million cars off the road.

The six technologies that will be included in the energy efficiency demonstration are air conditioning that uses variable refrigerant flow; heat pump water heating; ductless residential heat pumps and air conditioners; hyper-efficient residential appliances; data center energy efficiency; and light-emitting diode (LED) street and area lighting.

Commercial Cooling and Heating

Space cooling and heating accounts for 17% of total electricity use in the commercial sector. Currently, the most commonly used technology in commercial buildings relies on air conditioning systems with air ducts and fixed-speed fans. Such systems are relatively inflexible and inefficient because of the need to move large volumes of air throughout a building.

The demonstration will include air conditioning and heating technologies that achieve greater efficiency by circulating a refrigerant through pipes to space-conditioning units in each climate zone. Such variable refrigerant flow (VRF) systems reduce operating costs by controlling the amount of refrigerant that flows from a central heat pump compressor to individual evaporators in various parts of a building. VRF systems provide more-precise temperature control in a given zone, enhancing comfort and allowing some rooms to be heated at the same time others are cooled.

Ductless VRF systems are widely used in Japan, in about half of medium-sized commercial buildings and a third of large buildings. High energy costs and retrofit opportunities have created a strong demand in Europe. In such installations, energy savings of 10–40% have been reported.

Barriers to Address

VRF systems face a variety of barriers in the United States, including a relatively long payback period, consumer concerns about reliability and availability of service, lack of an established supply chain, insufficient verification of performance, and concerns about integration with the utility power system. EPRI's demonstration of VRF systems at several sites in different climate zones will focus on providing empirical data on which to base a business case for their purchase and installation.

Residential Ductless Heat Pumps

A conceptually similar ductless heat pump (DHP) system for residential applications employs a highly efficient ac/dc inverter to drive fans and compressors that can ramp up and down to quickly match the cooling and heating load of a residence. This heat pump system features an outdoor compressor, reducing the noise level inside. Cooled or heated refrigerant circulates through insulated lines to fan-coil units located in various living spaces. Individual thermostats can be set to the temperature desired for each indoor fan-coil unit.

Compared with the use of conventional electric space heaters or air conditioners, DHP systems offer improved comfort, less noise, and energy savings of 10–30%. DHP technology is widely used in Europe and Asia, commanding a market share of more than 50% in Japan as well as limited use in Hawaii.

Barriers to Address

Codes and standards in overseas markets are more favorable toward DHP systems than are codes in the United States, where most residences use central ducted systems to deliver cooling and heating. Another major barrier is the initial cost of DHP: $3,000 to $5,000 per ton of capacity (the amount of energy required to melt a ton of ice in a day, or about 12,000 Btu)—several times the cost of a conventional, forced-air system. In addition, most consumers are unaware of the advantages of DHP, and many contractors are not yet qualified to install these systems.

The EPRI demonstration will provide empirical data on DHP performance, on actual efficiency in the field, and on life-cycle costs. The findings will be shared with the U.S. Department of Energy (DOE) and various standards-influencing organizations for their consideration during the process of developing new standards and codes. If DHP measures up, this demonstration could prompt the more widespread substitution of electric heat pumps for gas- or oil-fueled residential heating and cooling systems. Until now, the cost and performance constraints of heat pumps have largely limited their use to warmer climates, but the deployment of DHP systems could substantially increase penetration and enhance the efficient use of energy.

Heat Pump Water Heating

Water heating accounts for 9% of U.S. residential electricity consumption. The application of heat pump technology to residential water heating could provide a reduction of up to 50% in energy consumption, compared with conventional alternatives. Heat pump water heaters (HPWHs) could also provide the additional benefits of limited space cooling and dehumidification at no additional cost.

HPWH systems are now manufactured by a limited number of relatively small companies in the United States, and DOE has given the technology its ENERGY STAR® efficiency label. Major U.S. manufacturers are expected to introduce their own lines of HPWH systems next year. Market penetration is much more advanced overseas, however, and Japanese manufacturers have gone a step further by introducing a line of "Eco-Cute" HPWHs that use carbon dioxide as a natural refrigerant, eliminating the threat of ozone depletion.

The Daiken Eco-Cute heat pump water heater, left, is instrumented for evaluation at EPRI's Living Laboratory in Knoxville, Tennessee. The high-efficiency unit also includes an outdoor component.

Barriers to Address

The most significant barrier to broad adoption of HPWH systems in the United States so far has been the perception of inadequate product reliability and insufficient installation and maintenance infrastructure, including the lack of contractors and skilled labor trained in HPWH technology. These factors have added to a high initial cost, resulting in poor life-cycle economics. The EPRI demonstration will focus on identifying improvements in product design and market infrastructure.

Efficient Data Centers

Data centers, which house high concentrations of computing equipment such as servers critical to corporate information technology, are among the fastest-growing and most energy-intensive types of buildings. Servers consume about 1.2% of the nation's electricity, and that share is expected to grow with the proliferation of data centers. But the energy inefficiency of most data centers not only wastes energy—for every 100 watts (W) of computing power, about 145 W is lost to power supplies and ac-to-dc conversion or is dissipated as waste heat—but also limits how much computation can be performed on-site.

EPRI's project will demonstrate a variety of strategies for improving the energy efficiency of data centers, including development of efficient power supplies, optimization of cooling and ventilation technologies and physical configurations, minimization of power distribution and conversion losses, and development of server virtualization software.

More than 3.1 billion power supplies are used with servers and personal computers, consuming about 3–4% of all electricity used in the United States. Improving the efficiency of computer and server power supplies could lower overall U.S. electricity use by 1–2%, for savings of $3.4 billion to $6.8 billion per year. Prior EPRI work in testing and specifying efficient desktop computer power supplies has helped pave the way for an ENERGY STAR® designation for power supplies. The same work has been the technical foundation for the 80 PLUS program, which provides incentives for PC power supply manufacturers to produce more-efficient units.

This project will evaluate the power supply efficiencies of data center rack equipment, such as servers. It will also assess opportunities to reduce thermal losses and, as a result, lower cooling loads. For every kilowatt-hour (kWh) saved at the server plug, another 1 to 1.5 kWh can be saved through reduced air conditioning requirements in large commercial data centers. In addition, eliminating a number of power supply conversions will increase the overall efficiency by avoiding the loss inherent in each conversion. Also, the continuing development of new software technology will cut down on the number of servers needed, thereby reducing total power and energy requirements.

Barriers to Address

A major component of the demonstration will be to collect product-specific performance data on various manufacturers' power supplies as they are deployed on utility systems.

Implementing energy efficiency measures may result in disruption to data center operations. Any retrofit upgrades would need to be scheduled with major overhauls of the complete data center.

"Hyper-efficient" Appliances

EPRI has identified a set of residential appliances that may use as little as half the electricity required by conventional U.S. models.

In some Asian countries, market penetration of hyper-efficient appliances approaches 80%, but none of these units are commercially available now in the United States. Research conducted by EPRI indicates that two of the most promising technologies in the demonstration program are an inverter-driven refrigerator and a heat pump clothes dryer. The refrigerator has the potential to reduce energy consumption by about 30%, compared with conventional models, because the inverter drive provides variable-speed operation. The clothes dryer delivers potential energy savings of up to 30% because the heat pump technology reclaims the heat and dehumidifies the recycled air. This is much more efficient than conventional resistance or gas heating, which vents the hot, saturated air through an exhaust after a single use.

Barriers to Address

High electricity prices in Europe and Asia, coupled with government policies, have provided the early impetus for these technologies. Adapting them for the U.S. market is expected to be a lengthy and costly process, after which extensive testing and demonstration will be required before they are accepted by consumers and trade organizations. A key task of the demonstration project is to identify barriers to deploying them in the United States. Understanding consumer reaction to the unfamiliar designs or to the results achieved will be a goal. Nationwide tests will benchmark appliance performance, and the results will be used to build an informational database on the technologies.

LED Street and Area Lighting

Conventional street and area lighting systems today rely mainly on high-intensity discharge (HID) lamps. Whereas HID lighting is approximately 75% efficient, LED efficiency is about 90%. The new technology may require less maintenance as well. It will be necessary to better understand the impact of the different color rendition of LEDs, particularly in comparison with the yellowish light of high-pressure sodium HIDs or the bluish hue of mercury vapor HIDs.

Engineers replace metal halide downlights with LED fixtures in the Living Laboratory's parking lot.

Barriers to Address

The EPRI demonstration will focus on understanding performance, energy consumption, maintenance costs, and the lifetime cost of ownership, and it will investigate susceptibility to voltage sags, swells, and transients. The study will also examine the human perception of LED street and area lighting as it relates to security and safety.

EPRI as a Deployment Facilitator

EPRI's Industry Technology Demonstration on Energy Efficiency is now enrolling participants and selecting 45 host utility sites to field-test the six technologies. An expected nine-month preparation phase, including equipment installation and test design, will be followed by roughly two years of data collection. EPRI will establish the program's scope and manage each demonstration project. After testing is complete, program participants will work with manufacturers and industry groups to identify the best ways to achieve broader market penetration of the most promising new technologies.

"These demonstrations are intended to lay the groundwork for understanding the impact of several highly efficient electrical end-use technologies in the United States," said Tom Reddoch, EPRI's director of energy utilization. "Although most of these technologies are already being used abroad, considerable work will be needed to adapt them for use in this country and to reach utility and consumer acceptance. EPRI's demonstration program can play a critical role in accelerating this process."

This article was written by John Douglas, science and technology writer. Background information was provided by Omar Siddiqui (osiddiqui@epri.com).

Omar Siddiqui is a senior project manager and chief strategist for energy efficiency in the Power Delivery and Markets Sector's Energy Utilization program area. His work focuses on energy efficiency, demand response, dynamic pricing, and the emerging smart-grid infrastructure. Siddiqui joined EPRI in 2007 with more than ten years of experience in the energy efficiency arena, most recently with Global Energy Partners. He received a B.S. degree in chemical engineering from Stanford University and an M.B.A. from the Anderson School at the University of California at Los Angeles.

DATELINE EPRI

News and events update

Federal Grant Award: EPRI to Assess U.S. Wave Energy

PALO ALTO, Calif. – The U.S. Department of Energy (DOE) awarded EPRI a grant of $500,000 to assess U.S. wave energy resources and develop a geographic information system database. The project will determine the resource base, the maximum wave energy potential, and annual potential electrical energy production. EPRI will develop a methodology to gauge the energy potential from all coastal states, providing information and data necessary to optimally site wave generating stations. For more information, contact Roger Bedard (rbedard@epri.com, 650.855.2131).

EPRI, U.S. DOE Convene Global Superconductivity Conference

OAK RIDGE, Tenn. – EPRI and the U.S. Department of Energy brought together researchers, technology companies, and utilities to share information and compare notes on the state of the art in superconductivity. Participants were updated on demonstrations of commercial prototypes for new high-temperature-superconducting cables, cryogenic refrigeration systems, transformers, and superconducting fault limiters. One project highlighted was the installation and testing of a one-mile superconducting cable being installed by Entergy in New Orleans, sponsored by DOE and with analysis support from EPRI. Projects from Korea and Japan were also reviewed. For more information, contact Steve Eckroad (seckroad@epri.com, 704.595.2223).

NRC Commissioner Visits EPRI Lab Facilities

CHARLOTTE, N.C. – Commissioner Gregory Jaczko of the U.S. Nuclear Regulatory Commission visited EPRI's nuclear facilities in Charlotte to increase his familiarity with how EPRI's research activities can help inform the regulatory process. EPRI staff briefed Jaczko on such topics as fire protection, spent fuel management, and materials. He toured laboratories focused on nondestructive evaluation, weld application, and bolting.

Annual Global Climate Change Seminar Attracts Top Researchers in Diverse Fields

WASHINGTON, D.C. – Scientists and economists from diverse fields joined EPRI researchers to examine a number of issues. Among the ideas presented:

- Developing nations' CO_2 emissions growth was underestimated, and their emissions will likely exceed those of developed nations by 2010. This decreases the likelihood of meeting some CO_2 concentration targets and increases the urgency for low- and non-emitting technologies.
- Reducing utility emissions significantly requires either using less coal or capturing CO_2 from coal plants. With existing coal-fired generation's low cost compared with alternatives, relatively high CO_2 prices may be required to effect near-term emissions reductions.
- "Geoengineering" may mitigate climate changes by such means as large-scale atmospheric introduction of compounds to offset greenhouse effects. Potential drawbacks include unintended effects, unilateral action by a nation or group, and reduced impetus to limit emissions.

Organizations participating included the Massachusetts Institute of Technology, Stanford University, the University of Calgary, Johns Hopkins University, the U.S. Energy Information Administration, and the University of Maryland's Joint Global Change Research Institute. The 2009 Climate Change Seminar will be held May 20–21 in Washington, D.C. For more information, contact Tom Wilson (twilson@epri.com, 650.855.7928).

Materials Aging Institute Hosts First Conference on Plant Materials

MORET SUR LOING, France – In January 2008, EPRI was joined by EDF and Tokyo Electric Power Company in founding the Materials Aging Institute (MAI), a collaborative research facility in France that will examine the critical link between materials science and power plant component performance and degradation. In November, MAI hosted its first conference at EDF's research and development facility in Moret Sur Loing, where participants discussed issues such as corrosion, fatigue, and irradiation aging in light water reactors, as well as chemical and other strategies to mitigate and manage these conditions.

Asian Leaders Hear Call for Coal Technology Advancement

BEIJING and MACAU – In late October, EPRI Director of Generation Stu Dalton provided EPRI's assessment of the need for progress in decarbonizing the electricity industry at two meetings in Asia:

- The Conference of the Electric Power Supply Industry, the largest forum for the power industry in Asia
- An international seminar hosted by the China Power Investment Corporation, which is working with the United Nations Development Program on a project titled "Energy Conservation and Environmental Protection by Power Generation Companies"

Dalton underscored the importance of advanced coal generation and the need to accelerate development and demonstration of carbon capture processes.

Australian, New Zealand Leaders Discuss Major Component Reliability

NOOSA HEADS, Australia – More than 130 electric utility leaders from Australia and New Zealand attended a series of workshops conducted by EPRI's Major Component Reliability (MCR) department in October that gave participants a chance to share experiences and explore ways to improve availability and reliability, as well as to help with technology transfer and to help shape future EPRI research. Topics included boiler life availability; cycle chemistry; steam turbines, generators, and balance-of-plant; fossil materials and repair; and heat recovery steam generator dependability. For more information, contact Tom Alley (calley@epri.com, 704.595.2066).

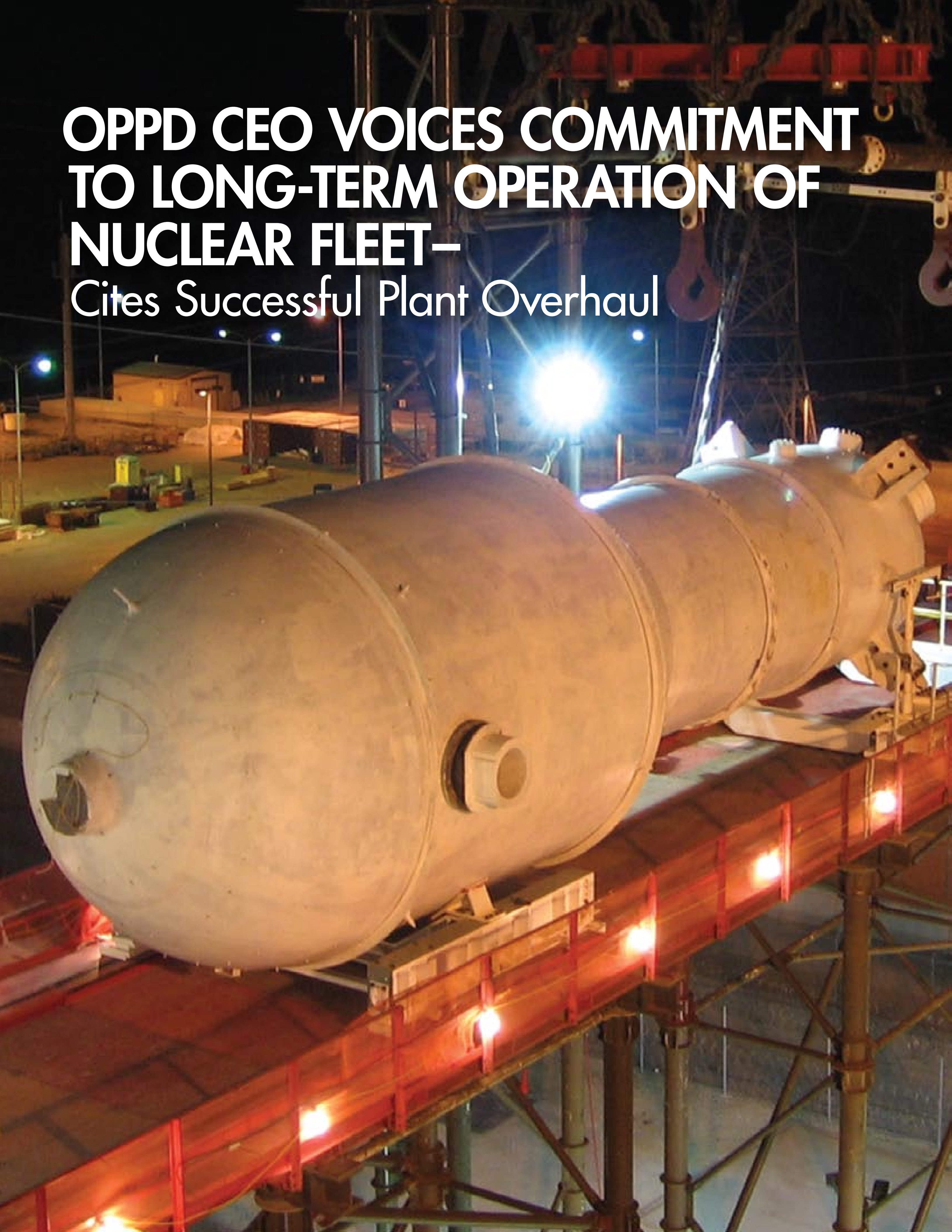
KHNP Signs Three-Year Agreement

SEOUL, South Korea and PALO ALTO, Calif. – Korea Hydro & Nuclear Power Company (KHNP) signed a three-year membership agreement with EPRI's nuclear sector, effective in 2009. KHNP operates 20 nuclear reactors in South Korea and is Korea's sole nuclear operator. KHNP has initiated a plan to increase Korea's nuclear generation share from 36% to 59% by 2030.

EPRI CEO and President Steve Specker and KHNP CEO and President Jong-Shin Kim with the newly signed membership agreement.

OPPD CEO VOICES COMMITMENT TO LONG-TERM OPERATION OF NUCLEAR FLEET–

Cites Successful Plant Overhaul



Omaha Public Power District is the 12th-largest publicly owned electric system in the United States, serving a 5,000-square-mile area in Nebraska with 2,548.8 megawatts (MW) of diversified power generation: 46.3% coal, 18.9% nuclear, and 34.6% oil and natural gas, with 0.2% landfill-gas and wind. In 2006, OPPD completed a successful 85-day outage at its Fort Calhoun station, a 482-MW nuclear power plant, in which most major components and systems were replaced or refurbished. OPPD Chief Executive Officer Gary Gates discussed the reasons for OPPD's successful project and its confidence in the long-term operation of the world's existing nuclear power fleet.

EJ: OPPD has demonstrated its commitment to the long-term operation of its assets. Why is that so important to both OPPD and the utility industry?

Gary Gates: Well, there are three basic points there for us. Capital costs of new construction are so high that the longer you maintain your existing infrastructure —there's just a tremendous cost benefit. Second, as we look forward, we are very comfortable with nuclear power. We have operated it for a number of years, and our board is comfortable with it, so it was not a stretch to want to continue to run our nuclear assets further into the future. Third, nuclear is a carbon-free asset, and those are just increasing in value. So from both the business and the philosophical perspective, it was the right thing to do for our company.

It made sense to operate Fort Calhoun as long as possible. We are like most full-scope utilities that have all the forms of generation. With us, this is not a change in philosophy to run units a long time—we have done it with our coal units, we have done it with our gas turbines—and so going for 80 years for a nuclear unit, going past the current 60, is not a stretch for us philosophically. We have done that with power stations forever.

EJ: OPPD's actions really represent an industry-leading vote of confidence, don't they?

Gary Gates: We think so. We put about $400 million into the plant, and it allowed us to do a lot of things proactively.

EJ: What major components and systems did you look at on the front end?

Gary Gates: We knew the steam generators were going to need to be replaced—

Photo: OPPD

"We are in this for the long haul." –Gary Gates

particularly looking at 40 more years—and the same thing with the reactor head. But we had only about 5% plugging in the steam generator after 30 years of operation. Our pressurizer had no problems at all, but as long as we had a hole in containment, we said, let's change that out and make it the right size to uprate the plant. We factored in a 17% uprate, and we're proceeding with that now.

EJ: So materials degradation or operational issues were not driving the timing of your work at Fort Calhoun?

Gary Gates: Right. What we learned from the industry and what we learned from EPRI was to look at our projections and choose an optimal time in our corporate financing to do it.

EJ: How far out were you looking as you assessed the plants and your needs?

Gary Gates: Our typical plan is 25 years. We are increasing that to 40 years right now in our integrated resource plan. That sounds like a long time, but I understand that India has a 250-year plan for their power. Isn't that an interesting way to look at it? I personally think that for the new units, we are going to plan for 60 to 80 years. It makes a huge difference on everything, from accumulating decommissioning costs to amortization.

EJ: But that is certainly realistic, isn't it?

Gary Gates: Oh yes. I think for the new designs, we need to factor in an 80-year life, right from the get-go. And actually, for the units we are operating today, the 40 years was a financial number, not an operational limit.

EJ: When you were looking at Fort Calhoun, how did you assess risks and rewards?

Gary Gates: There was the finite risk that we would not be granted a license extension, and that obviously would have changed things. We were confident that we understood that risk—but as a short-term risk. The larger risk was that we would not be able to run the unit. The rewards were pretty obvious. We had a great asset, the plant was paid for, and we could run another 20 years. There was an operational risk, because as a single-nuclear-unit utility, we needed to continue to run the plant. But we were confident we could do it, and it would be a great asset for OPPD.

EJ: In addition to the major components that you mentioned, were there other critical systems or structures that you decided to include in the scope of the overhaul plan?

Gary Gates: Yes, we looked at the secondary side—major feedwater piping and steam piping. We replaced all the heaters and moisture separators on our turbine system, and the low-pressure rotors. We are going to replace the high-pressure rotors, but that is an upgrade piece for the power uprate. We did do some instrumentation, and we have some digital systems but have not gone to digital completely. We upgraded a couple of our containment systems, and about four years ago we put in a new condenser in preparation for this.

EJ: What gave you the technical confidence to proceed on so many fronts with such a hugely complex undertaking?

Gary Gates: The confidence we had was confidence in the industry. We relied tremendously on EPRI, which helped give us the technical confidence that we had the right solutions. Our board of directors had confidence in our operation of the plant and the fact that it absolutely made so much sense for us financially to keep Fort Calhoun in the mix. Also, being a rather small utility, we partnered with our vendors, making it essentially a turnkey operation; so they had a lot of skin in the game to make sure it went right.

EJ: They were instrumental in helping you schedule and stage the work?

Gary Gates: Absolutely. Mitsubishi Heavy Industries helped us look at some innovations with steam generators based on their experience with the internals. With Bechtel, we interviewed the teams who were being considered and included contract requirements for people with experience, who had done a good job elsewhere and were good to work with. We had people here that were doing their third steam generator replacement. They knew how to rig the cranes and the ways to get the reactor vessel head and the steam generator in and out. We sent people to do quality control for the big equipment in Japan. We had some Nebraska guys that got to like sushi really well, and they basically lived right next to the work and were there every day as our equipment was constructed.

EJ: How did the results match up with your goals?

Gary Gates: Our goal was to complete the outage in 90 days, and we did it in 85 and were about $36 million under budget. We had anticipated about two to three shutdowns as we came up with new equipment, but the plant returned to operation and stayed at 100% for 280 days.

EJ: What else contributed to your success?

Gary Gates: We took 18 months just to optimize the choreography—where to put the new equipment, the temporary structures to house and assemble it, where you're going to dispose of your equipment. It was so finely tuned that we had the old head and the new head passing each other at the gate—one to be installed and one wrapped, ready to go to storage. There was no wasted motion; things just moved continuously. We laser-surveyed the containment ahead of time, we put the new steam generators in, and I think they were three-thousandths [of an inch] off in lining up

"Nuclear energy is carbon-free, it's safe, and it provides stability and diversity for our fuel mix. It answers a lot of basic needs if you are building a good, forward-looking utility."

heads and nozzles, which was perfect. I think the new technology giving you the ability to size your components and align them is something that people underestimate—the ability to survey and then translate that to manufacturing. It's not like the old approach, where you measure it, then see where you are.

EJ: Going back to a point you made earlier about the role of EPRI, where was OPPD able to realize value from collaborating with EPRI?

Gary Gates: I can think of several of the reports—the life-cycle management tools, the examination techniques that you put out for pressurizers and steam generators—that helped us in the end to make informed financial assumptions. For example, there's the question of whether to replace major components. Through EPRI's work, we were able to see that if we didn't replace them, pretty soon our inspection dollars per outage would have paid for the new components. With your inspection reports, we were able to do much more work in parallel during the outage, instead of doing things in sequence. We used a lot of your coating information as we looked at coatings, not only for the nuclear part but for our replacements on the secondary side. We used EPRI condenser technology reports in sizing our new condenser, deciding what materials we wanted, and deciding if we could sectionalize the condenser. Putting a condenser in a plant is harder than putting a steam generator in, because you've got a lot more pipes and stuff to contend with when you're trying to get down in the basement of your turbine building. We used air floaters—floated these things in, and it was quite a process—but we had huge computer modeling where we again laser-surveyed, then did the computer model on how we were going to work these things in.

"Our goal was to complete the outage in 90 days, and we did it in 85 and were about $36 million under budget. The plant returned to operation and stayed at 100% for 280 days."

EJ: So, given what you have learned from Fort Calhoun, what do you think is a feasible life span for a nuclear plant?

Gary Gates: I would say 80 years, without question. And I think if we do the new ones right, a 100-year lifetime is easily achievable.

EJ: What can EPRI and our members learn from OPPD's experience and success?

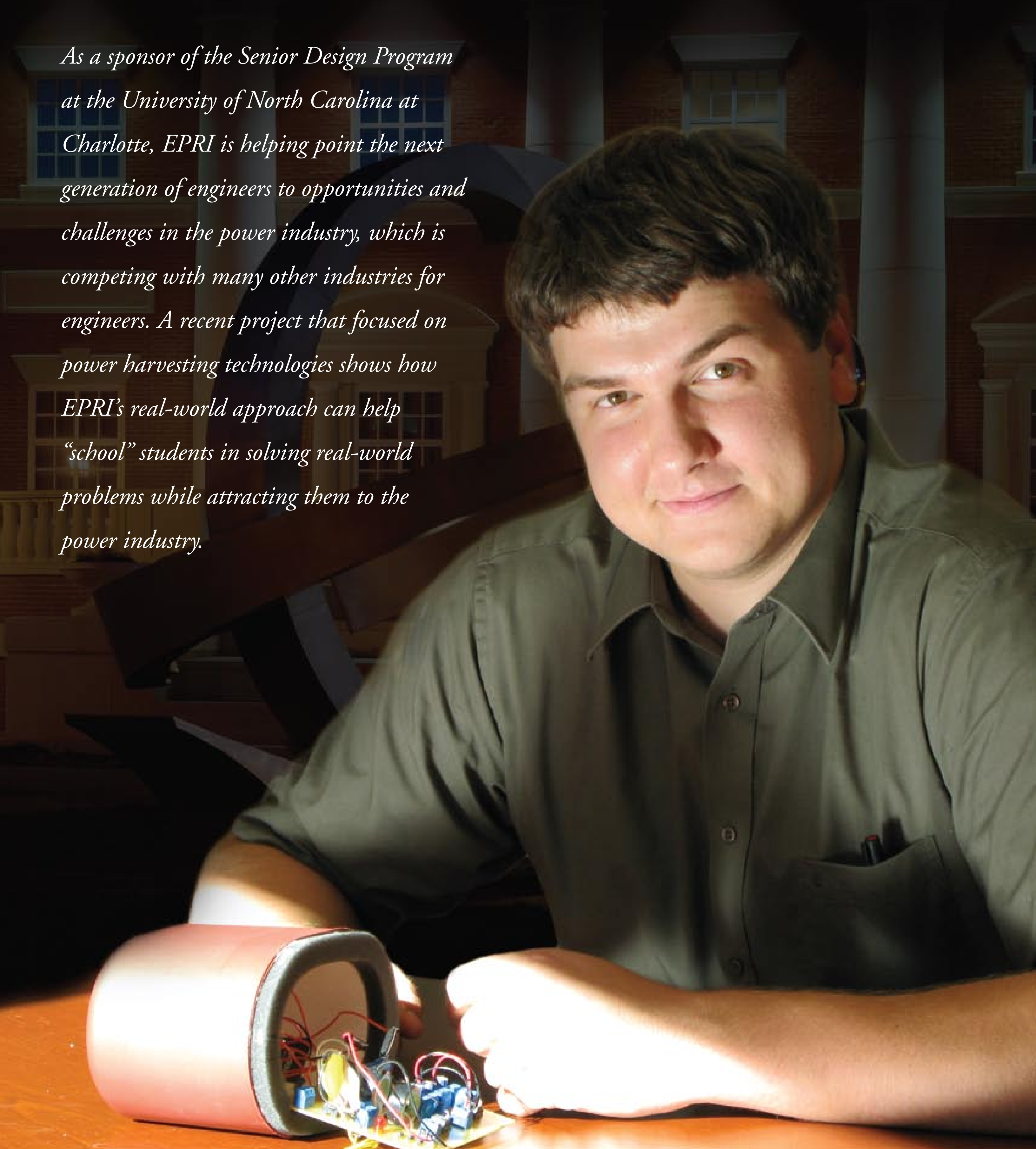
Gary Gates: When you go into a refurbishment like this, or to extend plant life, even if the system says 20 years, design it and buy components for 40 years. That gives you a margin. Second, take advantage of the industry, including the operating experience that's out there. We went to a lot of sites that were doing this kind of effort, to learn from them. In an operation this big, minimize the number of rookies. We need to have some rookies, because the industry needs to prepare them. You can't have a first-time team all the way through or it is going to be hard, hard to get there. Planning is the secret. Sweat the details as far out as you can on how you are going to coordinate things. We had developed a separate division, we put about 40 people in it, and they had various pieces of this outage. Then we matched them up with the vendors, but a lot of the scheduling tools came from the vendors. We put together the new division three years out, because we did not want them worried about any of the operating issues.

EJ: What does your work at Fort Calhoun mean for nuclear power and the industry?

Gary Gates: We have great assets in our existing nuclear fleet. I see no technical reason we can't run these plants for 80 years. You ask yourself, is there a financial issue? And every time you look at the finances, it is positive. So from a business case, it makes sense. Nuclear energy is carbon-free, it's safe, and it provides stability and diversity for our fuel mix. It answers a lot of basic needs if you are building an ideal utility—a good, forward-looking utility. I have a clear message for everybody: we are in this for the long haul, no question.

Student Program Opens Doors to Innovation and the Power Industry

As a sponsor of the Senior Design Program at the University of North Carolina at Charlotte, EPRI is helping point the next generation of engineers to opportunities and challenges in the power industry, which is competing with many other industries for engineers. A recent project that focused on power harvesting technologies shows how EPRI's real-world approach can help "school" students in solving real-world problems while attracting them to the power industry.



EPRI's Office of Innovation has joined with the University of North Carolina at Charlotte's William States Lee College of Engineering to help sponsor the school's Senior Design Program (see sidebar) in order to focus efforts on power industry issues and to help steer graduating engineers to the power industry. Under the program, small teams of students are assigned to work on individual projects, supervised by an EPRI project manager and UNC Charlotte engineering faculty. Over two semesters, the teams develop their projects to demonstrate their technical and project management competencies. As sponsor, EPRI helps monitor the students' work, receives the results of their completed projects, and in some cases extends an offer of employment. EPRI-sponsored projects have ranged from a software interface for turbine alignment procedures to strain measurement for equipment life assessment.

Power Harvesting

One of EPRI's recent student projects was aimed at developing a device that "harvests" unused energy to supply power to sensors that monitor the condition of equipment in power plants, substations, and other locations. The ability to add sensors is sometimes limited by the challenge of powering them without incurring additional operating costs or maintenance.

One possible solution is power harvesting, or efficiently capturing and converting untapped energy from nearby indoor or outdoor sources, including wind energy, solar power, vibration energy, thermoelectricity, and physical motion.

Brandon Rummage, then an electrical engineering major and EPRI student intern, was joined by Tom Donnelly, a mechanical engineering major, on a project to design a device that would capture the energy from more than one nearby source, convert it to electricity, and store it until needed.

EPRI and the team agreed on a number of requirements. The harvesting device must be small and include two major subsystems: several power harvesting transducers, each housed in a separate module; and a central electrical circuit, which would condition the power and ultimately charge a battery. The device was also to provide a constant 5-volt (dc) supply and visually display charging via a light-emitting diode, or LED.

Several potential sources of energy for harvest were explored. The modes that proved to be the most energy dense were wind energy harvested by a small turbine attached to a brushed dc motor; solar energy harvested by an off-the-shelf solar cell; and vibration energy produced by the operation of rotating equipment (e.g., motors and pumps) and harvested by a custom-designed magnet-coil inducer.

The team had initially considered two other sources as well: heat and EMF (electric and magnetic fields). Heat was eliminated because of its low energy density and the difficulty of capture. EMF was discarded because of challenges in accessing the source.

Once the power harvesting modes were selected, the team designed the electrical circuit to condition the output from all three sources to a constant dc supply. The circuit allows each source to contribute power if it's available and allows the system to continue operating with one, two, or all three sources powering the battery.

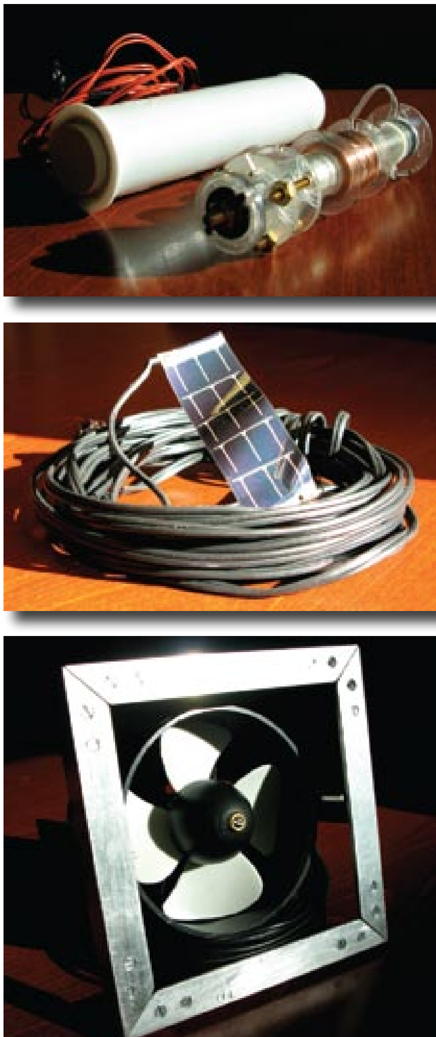
The final prototype power harvesting device met the size requirements. The electrical circuit was 2 inches by 4 inches by 2 inches, and each transducer was less than 6 inches long. The device was demonstrated to be capable of producing 790 milliwatts (mW) from wind, 1.2 mW from vibration, and 543 mW from solar power (indoors). Although power from the vibration harvester was minimal, it proved the concept and showed that a magnet-coil inducer made for less than $100 could function adequately.

"While vibration and solar power harvesting had been done before, the unique thing about the project was that we were combining different energy sources into a reliable, consistent energy source," said UNC Charlotte professor Ivan Howitt, who supervised the student project. "In a

The Senior Design Program

- The Senior Design Program is a graduation requirement for undergraduate engineering majors at the more than 350 U.S. colleges and universities accredited by ABET, Inc. (formerly the Accreditation Board for Engineering and Technology).
- Projects within the program are intended to be innovative, with clearly defined requirements and solutions.
- Participation in the program is designed to be a culminating experience that will apply the knowledge of basic engineering principles learned in three years of undergraduate classes to a practical problem.
- Students must solve a practical problem that is coupled with an industry need.
- UNC Charlotte's program was initiated in 2005, growing to 80 students in Fall 2007 and 112 in Fall 2008. The projects are sponsored by area industries. In the most recent year, the 23 industry sponsors included Areva, Duke Energy, Irwin Tools, Microsoft, NASA, Schweitzer Engineering Labs, and the Shaw Group. Industry sponsors are asked to provide a $5,000 contribution per project for parts, materials, off-campus travel, and the upkeep of the university's engineering shops and laboratories.
- Teams are made up of two to six students from diverse engineering backgrounds, including civil, mechanical, electrical, and computer engineering.
- Projects should require no more than 1,000 work hours. Each student is expected to work 10 to 15 hours per week over two semesters (21 weeks).
- Students' work is monitored in weekly or biweekly meetings with a faculty advisor and an industry sponsor.

Opposite: Brandon Rummage with the power harvesting device.



The UNCC team used an off-the-shelf piezoelectric flashlight, a small photovoltaic cell, and a propeller for a hobbyist's remote-controlled airplane to harvest energy from vibration, sunlight, and wind, respectively.

broader sense, it opens up the whole concept of how you look at other environments and how you might collect all the ambient energy there and use it in ways to reduce costs and improve efficiencies."

A Collaborative Approach

Assigning engineers from different backgrounds to work as a team on a project is at the heart of the Senior Design Program. "The multidisciplinary structure of the teams is designed to simulate the actual work environment in a typical company," said Dr. William Heybruck, director of UNC Charlotte's Industrial Solutions Laboratory, which supervises the program. "Each project has electrical engineers working with civil, mechanical, or software engineers, so the students understand that the solution to the problem does not belong to just one of them. Each of them has to cooperate with the others and learn to work with different styles in language, discussion, and documentation."

Over the two semesters, the senior design projects follow a standard time line that progresses from concept to demonstration. In the case of EPRI's power harvesting project, the students worked in the first semester to research sources of untapped energy found in a typical power plant or substation, narrow the sources to the best for this project, define the requirements of the device, develop initial designs for several sources, and fabricate an electronic circuit to combine all the sources into a device meeting the specified requirements.

In the second semester, the students refined the design, drew up specifications, and fabricated and tested prototypes. The project culminated in a demonstration and poster session at the Senior Design Expo, attended by all the Senior Design Program students and their sponsors.

Learning Project Management

Beyond teaching technical skills, the senior design projects are intended to help students practice project management skills—clarifying customer requirements, budgeting, critical-path scheduling, coordination, and presentation. "Part of what they learn is that there isn't a single correct solution," said Howitt. "It's not like a textbook, where there's a single right answer. It's a real engineering problem, and you're working to get a good, practical solution. It may not always be the most direct, most sophisticated technical solution, because you're working within the constraints of time and money."

That's an important lesson for the student teams. "In the past, typical senior design projects tended to focus just on engineering design and fabrication—and not enough on budget and real-world requirements," said Aaron Hussey, the EPRI project manager who supervised the power harvesting project. "The UNC Charlotte projects encompass everything from defining what a customer wants to developing a budget, writing a project plan, designing and building a prototype device, and then closing the loop and making sure that prototype meets the customer's requirements within budget. The students are getting exposure to both engineering and project management."

In the power harvesting project, the team faced this harsh financial reality when the students sought to harvest energy from vibration. "We found off-the-shelf vibration transducers online," said Rummage. "But one of them cost more than our entire budget. So we had to fabricate our own from scratch."

The challenges that arise in the course of the projects sometimes offer insights into the students' work styles. "There's always a point in this type of project where the work reaches a difficult spot, and the students have to be creative, push through, and find new solutions," said Hussey. "In the power harvesting project, an early prototype didn't function properly, and one of the students had to work night and day to get it running. In an interview, where you normally recruit new hires, you don't get a feel for that kind of resolve—you only get it once they come to work for you. I just can't say enough about this program's value for evaluating students. It's like an extended job interview."

Harvesting Excellence

At the end of the year, at the Senior Design Expo, the EPRI-sponsored team demonstrated a power harvesting device capable of reliably capturing and storing energy from three sources. EPRI offered Rummage a job in its Charlotte office, where he now works as an engineer in the Power Delivery and Utilization Sector. On average, about half the students in the UNC Charlotte Senior Design Program are subsequently employed by industry sponsors, with even more receiving job offers.

The prospects are good for training more engineers at UNC Charlotte for careers in the power industry. This year the university announced plans to build its new $57 million Energy Production and Infrastructure Center (EPIC). Scheduled for completion in 2011, EPIC aims to become a national center for excellence, focusing on educating power and electrical engineers, conducting applied electrical research in collaboration with regional industry, and being a "center for electrical engineering opinion leaders." According to the university, the center's mission will be to "address the severe shortage of trained engineers capable of servicing and replacing an aging fossil fuel and nuclear infrastructure as well as developing future infrastructures for wind, solar, and biofuels."

EPRI is represented on EPIC's board of directors and is contributing its perspective to the center's planning for the near-term and strategic needs of the marketplace. With energy a national priority, centers like EPIC will offer important opportunities for utility sponsorship to support the education of the next generation of engineers.

As for the power harvesting work, Hussey said he hopes the project will eventually become full-fledged EPRI research. "The cost-effective deployment of additional power plant sensors will be enabled through power harvesting technology, eliminating the need for batteries in the field that must be maintained periodically," he said. "This design is a unique combination of different power sources. I haven't seen any other organization working on that kind of electronic circuit. And the energy sources as prototyped are low-cost options, compared with what's currently commercially available. I definitely can see an industry benefit from this kind of technology."

This article was written by Jonas Weisel. Background information was provided by Aaron Hussey (ahussey@epri.com) and Brandon Rummage (brummage@epri.com).

The Power Industry Challenge: Recruiting to Reverse the Engineering Exodus

- A 2005 study of the utility industry by the Hay Group management consulting firm reported that 40% of senior electrical engineers will be eligible for retirement by 2009. Universities in the United States are graduating fewer engineers specifically trained for the utility industry than they did 30 years ago—about 500 per year nationally, compared with 2,000 per year in the 1980s.
- The Edison Electric Institute reported last year that, when nonretirement attrition is factored in, electric utilities could lose up to 46% of their total engineering workforce, or roughly 15,000 engineers, by 2012.
- Utilities must deal with the reduction in college programs and with competition from other industries, such as aerospace, biotechnology, and information technology. Energy companies have an image problem among graduates, who tend to view the power industry as less involved with cutting-edge technologies than the other sectors.
- Utilities are also losing opportunities for experienced engineers to transfer learned skills and methods to new colleagues—a critical part of engineering career development—and for new hires to inject fresh, new ideas.

Brandon Rummage, center, is joined by EPRI sponsors Aaron Hussey, left, and Steve Hesler, right, and by UNCC project mentors Dr. Robert Cox, center left, and Dr. Ivan Howitt, center right, in a review of the project.

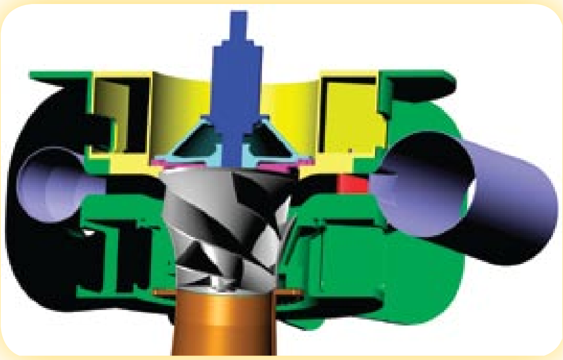
Aaron Hussey is a project manager for the Instrumentation & Control (I&C) and Automation program in the Generation Sector, where he is responsible for developing monitoring techniques and processes to assess equipment condition. Having worked as an EPRI student intern while in college, Hussey joined the Institute as an engineer for fossil and nuclear I&C projects in 2002. Earlier he was a manufacturing engineer at Corning and also worked at Turbocam Automated Production Systems. Hussey received a B.S. degree in mechanical engineering from the University of North Carolina at Charlotte.

Advanced Hydro Turbine Increases Safe Fish Passage

The U.S. Department of Energy (DOE) recently awarded EPRI a grant to continue development of an advanced helical, three-bladed runner that could dramatically reduce fish mortality in hydroelectric plants. The advanced turbine could minimize the need for more-traditional, less-effective fish protection structures and could also lead to additional hydroelectric generation—perhaps as much as 25,000 MW.

Interested companies are encouraged to join EPRI in pursuing this work under the DOE matching-funds opportunity.

Economical and low in emissions, hydroelectric power is a critical low-carbon energy option. Fisheries protection continues to concern regulatory agencies, and at many hydropower facilities, spawning and post-spawning fish can be injured or killed as they pass through the turbines. This environmental impact impedes the development of hydropower technology and affects the continued operation of existing facilities. Dam owners are often required to install and evaluate fisheries protection devices to meet regulatory requirements associated with operating licenses and permits.



Art: Alden

Traditional fish protection has focused on preventing fish from entering dam intakes—diverting them to bypass streams with screens and other physical structures, or attracting or repelling the fish with flashing lights, sound, or turbulence. The success of these schemes has been mixed, depending largely on waterway geometry and on fish size, age, and species. EPRI is seeking a more direct solution to the problem by supporting the development of "fish-friendly" turbines that inherently reduce fish mortality without reducing power conversion efficiency.

In 1996 EPRI, DOE, and the utility industry launched an effort to develop advanced hydro turbines that are more than 90% efficient and allow fish to pass through with a mortality rate of 5% or less. By 2001, the research had produced two turbine designs. The first, designed for large rivers, is currently being tested in the Columbia River. The second, designed for smaller rivers, is called the Alden/Concepts NREC turbine and features an innovative helix-shaped runner with only three blades. Pilot-scale tests have demonstrated mortality levels for many fish species below the 5% goal. DOE funding for this work ended in 2006, but EPRI has continued research and development to complete a full-scale design for commercial fabrication and field testing.

The next phase will entail producing an engineering design, fabricating a physical turbine model, and testing the model. EPRI will use the DOE grant for continued development of the Alden/Concepts NREC turbine. The award is part of a $10 million DOE solicitation for advanced water power projects. The DOE solicitation requires a minimum 50% industry funding match.

Under the development plan, Voith Siemens Hydro Power Generation Inc. (VSH) will produce a preliminary engineering design for the Alden/Concepts turbine. This will include design of the turbine spiral case, stay vanes, turbine head cover and gate system, and bearings and seals. All major components will undergo stress/strain checks to validate the design. VSH will then design and fabricate a physical model for performance testing. Testing will measure turbine efficiency, cavitation inception, power, pressure pulsation, gate torques, axial thrust, and runaway speed, as well as other performance factors. Results of these analyses will support refinement of the design and assessment of its economic performance relative to traditional hydropower turbine designs.

Successful execution of these tasks, all of which are scheduled for completion in 2009, will position the fish-friendly turbine for possible commercialization. Brookfield Renewable Power has indicated an interest in testing the advanced turbine (in about 2010 or 2011) at its 39-MW School Street project on the Mohawk River near Albany, New York. The U.S. Federal Energy Regulatory Commission granted the plant a license in 2007 to test the turbine. Stakeholders in the licensing process include the U.S. Fish and Wildlife Service, the National Oceanic and Atmospheric Administration, the New York State Department of Environmental Conservation, and local environmental organizations. All of these have concurred with plans for the turbine's deployment and testing and—pending favorable test results—with its adoption as a preferred technology for fisheries protection.

It is anticipated that deploying the advanced turbine could not only minimize mitigation needs for fish protection but could also result in an increase of up to 25,000 MW in hydro generating capacity. In addition, participating companies may realize credit toward state renewable portfolio standards, as well as carbon credits in the developing carbon-trade market.

For more information, contact Doug Dixon, ddixon@epri.com, 804.642.1025.

Electrochromic Window Coatings Promise Major Energy Savings

Peak electric loads in many commercial buildings could be reduced 20–30% if their windows could be made darker when exposed to sunlight and more transparent again when incident light is no longer so bright. Most of the savings would come from reduced cooling loads, and maximum potential savings could be realized if the degree of transparency in specific windows could be controlled by a building's energy management system in response to both changing light and electricity price signals.

Photos: Sage Electrochromics

Switchable electrochromic window coatings capable of providing such a light-adjusting response are now being developed, but they face two major hurdles. One challenge is to create a stable, solid-state coating that can withstand many light-dark transitions and not degrade because of exposure to ultraviolet light or long-term internal chemical reactions. Another challenge is to fabricate this coating as a low-cost, flexible film that can easily be applied to new or existing windows.

EPRI is addressing both of these challenges through a program to accelerate the development of solid-state electrochromics from a laboratory curiosity to a commercially important energy-saving technology. Electrochromism is a recognized phenomenon by which certain chemical compounds reversibly change color when a small electric current is applied; this color change persists after the initial current stops but can be reversed by applying a countercurrent. Because of cost and technical limitations, however, electrochromic technology has been limited to small-scale applications, such as digital displays.

Development of a flexible electrochromic coating is focusing on modifying the vacuum deposition process already used to create thin-film solar photovoltaic cells. Specifically, five layers of solid-state material will be deposited on a low-cost, transparent polymer substrate as it is drawn slowly between two reels. The top and bottom layers are made of a conductive oxide that provides electrical contact and serves as a moisture barrier. Between them, an electrochromic layer and an ion storage layer are separated by an electrolyte.

Applying a small voltage (about 2 volts) momentarily in one direction drives lithium ions from the storage layer to the electrochromic layer, where they bind with tungsten oxide, switching the layer to a dark state. Reversing the voltage takes the ions back to the storage layer and leaves the electrochromic layer in a clear state. Eventually, a self-contained power source such as photovoltaics could be used to provide the necessary voltage, enabling windows to function automatically or by manual control.

"Already we have demonstrated the use of the electrochromic and ion storage materials on a glass substrate, but we need to optimize the process and transfer it from glass to plastic," said Ammi Amarnath, EPRI technical leader for energy efficiency and demand response. "I expect that in about two years we can develop a fabrication capability to produce good thin-film samples in limited size and number. In another three years or so, I believe, we can achieve production-grade coatings and begin to market them."

If these targets can be achieved, electrochromic coatings could help utilities and their customers meet the tougher efficiency standards being developed for new buildings. One example is the Long-Term Energy Efficiency Strategic Plan recently adopted by the California Public Utilities Commission. It requires that all new residential construction provide "zero net energy" by 2020, with commercial construction to follow suit by 2030. This means that the building's annual consumption of electricity or natural gas from utility suppliers must be offset by a combination of energy-efficient building features and distributed generation.

"Adjustable-transparency windows that can be controlled by the customer could play a critical role in achieving these goals," said Amarnath.

For more information, contact Ammi Amarnath, aamarnath@epri.com, 650.855.1007.

Solar-Augmented Steam Cycles

Utilities need to develop solar energy projects to meet state renewable portfolio standards, demonstrate corporate leadership in mitigating climate change, and avoid fuel costs and emissions while diversifying their generation portfolios. But today most solar applications are not cost competitive with other power generating options.

That's why EPRI is leading research into solar-augmented steam cycles, which use steam generated by a field of solar-thermal collectors in a conventional fossil fuel–powered steam cycle. Solar augmentation is potentially the lowest-cost option for adding solar power to the generation fleet. Solar energy is typically at its highest intensity within a few hours of peak summer loads, making it a particularly attractive renewable option.


Photo: Acciona Group

EPRI is conducting parallel projects—looking at solar-augmented steam cycles for coal plants (1018235) and for natural gas plants (1016979)—based on results of a solar technology assessment in New Mexico (1016344) that evaluated the development status, cost, and performance of central solar plant designs. These projects will provide a conceptual design study and two detailed case studies for each kind of plant. Design options for existing plants will be analyzed, and new plant design options will be identified.

For more information, contact Cara Libby, clibby@epri.com, 650.855.2382.

Staying Active After Sixty

People are living longer than ever, which requires long-term financial and health planning so that they can maintain active lifestyles into their 80s and beyond. The same is happening with nuclear power plants. The oldest nuclear plants will be reaching their 40th birthdays in the next few years. Half of the existing U.S. nuclear plants have received extensions of their 40-year licenses to 60 years, and most or all of the remaining plants are also expected to extend their licenses to 60 years. Nuclear plant owners are now beginning to consider life extension to 80 years or more. (See "OPPD CEO Voices Commitment," page 20.)

"We have hundreds of billions of dollars of assets in our nuclear fleet—assets that are operating essentially around the clock and providing 20% of the power in the United States, carbon-free, at the lowest cost of any central power station," said John Gaertner, an EPRI technical executive based in Charlotte, North Carolina. "Jeopardizing this investment puts these benefits at risk."

To ensure that the investment will not be lost, EPRI will be conducting age-related nuclear plant research under a new Long-Term Operations (LTO) project. LTO efforts will support complementary EPRI engagement with the U.S. Department of Energy, the U.S. Nuclear Regulatory Commission, and global organizations such as the Materials Aging Institute to evaluate extended plant operations. "We are undertaking this project to identify the risks that challenge long-term, high-performance operation," said Gaertner. "We need to address those technical issues in time to prevent undesirable impacts on the industry or society." Structured to identify both risks and opportunities, the LTO project will seek solutions for issues that are longer term or that require resources greater than those available under current EPRI programs.

In late 2007, EPRI surveyed 47 U.S. utility executives on plant life extension: 87% thought it was at least somewhat likely that their companies would seek to extend plant operation beyond 60 years, and more than half thought it was very likely—primarily because of potential CO_2 restrictions and the economic competitiveness of the nuclear plants.

To achieve this goal, however, requires ensuring that the plants can continue safe, reliable operations decades beyond their initial design life spans. Three areas emerged as top research priorities: age-related degradation of metals in the primary system, aging of the concrete in the containment and other structures, and plant instrumentation and control (I&C).

While metal aging is a known area of concern that must be addressed, concrete aging has received less attention. Research is needed to study how concrete will perform beyond 60 years, when temperature, water, and radiation can accelerate aging. Regarding instrumentation and control, the I&C systems currently in place were selected for absolute safety and reliability rather than for advanced functionality. But because technology has advanced so far and so fast in recent years, it is now possible to capitalize on new capabilities while improving safety and performance.

Other areas slated for research include improved analysis of safety margins, automatic on-line monitoring of equipment to predict and prevent failures, availability and temperature of cooling water, aging of cable, and aging of buried pipe.

EPRI has allocated membership funds to provide support to the LTO project, beginning in January 2009. Under the collaborative arrangement with DOE, EPRI will also co-fund certain projects to be carried out under DOE's Light Water Reactor Sustainability Program, which received initial funding in October.

Because the long-term operational issues to be addressed through the LTO project are germane to all nuclear plants, global participation and engagement are expected. For example, the Materials Aging Institute—founded by EPRI, French utility EDF, and Tokyo Electric Power Company in early 2008—is conducting related research in metals aging and is also interested in the research on concrete.

If U.S. nuclear plants can extend operation to 60 years, why is it vital to begin the LTO research now? According to plant operators, even if license extensions are granted to all plants, it won't be possible to achieve the best reliability and cost performance without making improvements to address aging and obsolescence. Whether it turns out that companies are able to plan on operating these plants for 80 years or more will not only drive major refurbishment plans but also impact plans for new generation. Operators need to know a decade or more ahead of time whether they will be able to extend the life of these existing assets. Otherwise they will need the time to design, obtain permits for, and build new capacity.

"Plant owners tell us they need the information on the feasibility of further extension by between 2014 and 2019 in order to make their long-term decisions," said Gaertner. "Since our LTO objectives are chosen to achieve results in five years or more, we need to start the research now or we will miss that opportunity."

For more information, contact John Gaertner, jgaertner@epri.com, 704.595.2169.

Manhole Cover Restraint System Tested for Improved Safety

Manhole explosions are rare and result from various factors, but they can occur without warning. The energy released in a major manhole explosion can lift a 200-pound cast-iron cover from its frame, in some cases causing it to become airborne. Recent EPRI research confirms the effectiveness of a manhole cover restraint system that may prevent or limit damage caused by a manhole cover in the event of an explosion.

EPRI conducted the research in collaboration with Detroit Edison and manufacturer Stabiloc of Warren, Michigan. Stabiloc developed a controlled pressure relief mechanism, which was tested in a simulated working environment.

The cover is designed to remain engaged to the manhole frame in all but the most severe explosions. It uses two latches: a fixed latch and an adjustable breakaway latch equipped with two shear pins. In a minor explosion, the mechanism allows the cover to rise about two inches to relieve pressure and then fall back into its frame. In a more powerful explosion, the primary pin may shear, allowing the cover to rise another inch or so. In a major explosion, the secondary pin may shear to release the cover from its frame.

"EPRI's testing confirmed that the mechanism can restrain the cover while allowing it to rise slightly to release internal pressure," said Matt Olearczyk, manager of distribution research for EPRI. "The research team also determined the necessary pin sizes to provide controlled pressure relief and prevent roadbed damage for minor and moderate explosions."

Photo: Stabiloc

Detroit Edison has installed about 1,200 Stabiloc covers to enhance safety.

"This project was a landmark collaborative effort," said Vince Dow, Detroit Edison vice president, distribution operation. "The project produced an effective, elegant solution that improves worker and public safety."

Nirmal Singh, Ph.D., dielectric scientist, was Detroit Edison's lead researcher on the project. Detroit Edison has been an EPRI member for 30 years, and "this project stands out as a major benefit of our membership and a major benefit to our company," he said.

EPRI performed the testing at its facility in Lenox, Massachusetts. EPRI and Detroit Edison researchers used a series of explosions to evaluate the performance of covers with and without the controlled pressure relief mechanism, and with various sizes of shear pins in the locking mechanism. Test results provided performance data to help the team's engineers to optimize the cover's design.

For more information, contact Matt Olearczyk, molearcz@epri.com, 704.595.2257.

Testing and Data Analysis Under Way at Pilot Project for CO_2 Capture

EPRI's year-long program is under way to collect and analyze data for a pilot-scale version of a process that uses chilled ammonia to capture carbon dioxide (CO_2) from the flue gas of a pulverized-coal generating plant.

In earlier laboratory experiments, the chilled ammonia process demonstrated the potential to capture more than 90% of CO_2 at a cost projected to be far lower than that offered by other technologies currently available. For the pilot project, which represents a milestone in CO_2 capture efforts, the process has been scaled up to a 1.7-MWe system.

We Energies provided the host site and utilities for the scaled-up system at its Pleasant Prairie Power Plant in southeastern Wisconsin. Alstom, which holds the exclusive license to the chilled ammonia process, constructed and is operating the pilot project and is also providing funding. With the support of a consortium of 37 national and international utilities, EPRI is managing data collection in a series of engineering and environmental performance tests and will use the data to prepare a technical and economic evaluation of the process. The tests are designed to demonstrate proof of concept, establish the integrity of the process, measure energy consumption, and lay the foundation for applying the chilled ammonia process on a commercial scale.

As of October, several commissioning challenges had been resolved, the liquid sample collection/analysis routines were in place and working well, and the continuous data logging routines were in place. Additional instrumentation has been installed to quantify CO_2 product and makeup/blowdown flows.

The monitoring regime is documenting parameters in system operations and maintenance and collecting data on ammonia loss and makeup, process water loss and makeup, the purity of the CO_2 product, and the fate of various emissions (including sulfur dioxide, sulfur trioxide, nitrogen oxides, particulate matter, mercury, and hazardous air pollutants).

With sufficient detail from this pilot data collection, researchers will be able to estimate key factors affecting commercial-scale operation, including process thermal requirements and the impact on the plant's power cycle, material operating costs, equipment capital costs, levelized cost for CO_2 removal, and levelized cost of electricity.

Tests designed to optimize performance are looking at how altering process parameters can affect the process. These tests are investigating how changes in independent parameters, such as flue gas flow rate, strength of the ammonia solution, and process temperature and pressure, can affect dependent parameters, such as CO_2 removal and quality, use of heat and chilled water, and materials usage and disposal.

In a series of gas sampling campaigns, researchers are setting the independent parameters at optimal levels and then taking profiles of the flue gas composition and measuring the use parameters. Gas sampling has been conducted in March, July, September, October, and November and is planned for January 2009. Preliminary data indicate the potential for high CO_2 capture.

The chilled ammonia process involves three steps. First, the flue gas exiting from the plant boiler and air quality control system is cooled and cleaned before being sent to a tall CO_2 absorber column. There the gas mixes with a solution of ammonium carbonate, in which CO_2 is removed through the formation of ammonium bicarbonate. Finally, the solution is pumped to a regeneration system, where it is heated under pressure, reversing the absorption process and releasing pure CO_2.

The pilot project at Pleasant Prairie treats about 1% of the plant's flue gas and could capture up to 15,000 tons per year of CO_2. Because of the nature of this pilot plant, the captured gas is being released to the atmosphere, but eventually the pressurized CO_2 from such facilities will be transported for storage in appropriate geologic formations.

The chilled ammonia process holds promise for electric utilities because its parasitic load could be as low as 15–20% of the power plant's energy output, or about half to two-thirds the energy demand of today's most commonly used industrial carbon capture technology, an absorption process that employs a solvent called monoethanolamine, or MEA. The lower energy demand of the chilled ammonia process would translate into correspondingly lower cost increases in future applications of CO_2 controls.

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Tests on Aging Transmission Cables Help Prioritize Replacement

Electric utilities concerned about their aging power delivery infrastructure face a particularly difficult task as they consider whether to replace older underground transmission cables. A significant portion of the extra-high-voltage (230–345 kV) cables in the United States are high-pressure, fluid-filled (HPFF) units, many of which were installed in the 1970s and are thus approaching the end of their nominal 40-year life expectancy. One limitation in determining the actual condition of these EHV cables is that few samples of HPFF cable have been available for destructive testing.

Recently, Public Service Electric and Gas (PSE&G) worked with engineers at EPRI's Lenox laboratory to conduct a thorough battery of tests on a 36-year-old, 230-kV cable that had been removed from service. In addition to providing PSE&G with valuable information on the condition and estimated remaining life of this type of service-aged cable, the ongoing tests will contribute to the industry's knowledge of aging HPFF cables in general.

The first diagnostic test applied to the cable was dissolved gas analysis (DGA) on a sample of the pressurized oil that surrounds the central conductor and bathes the paper insulation wrapped around it. This type of analysis, which is not destructive and can be performed in the field, indicates whether there are gases present—such as hydrogen and acetylene—that could indicate breakdown of the insulation due to partial discharge or arcing. In the case of the PSE&G cable, no such gases were detected, indicating that the insulation was potentially still in good condition. DGA does not provide a complete picture as to the condition of service-aged insulation, however, so PSE&G desired to carry out a hot impulse test, which is a destructive evaluation.

For this test, a section of the cable was installed in a uniquely designed test rig at Lenox, heated to its normal operating temperature, and subjected to a series of increasingly higher-voltage impulses, such as it might experience from a lightning strike. Since no standards for lightning impulse testing had been established when the cable was manufactured (around 1970, by Anaconda Wire and Cable Company), it was tested to the current standard. That allowed comparison of the results with those of similar tests performed by EPRI in the 1980s on similar cables. In fact, the PSE&G sample demonstrated a withstand strength of at least 90% of the standard before it failed.

Currently, another section of the cable is undergoing a bending test designed to mimic the types of mechanical stresses it would experience under normal changes in electrical loading. Specifically, since a cable in service expands and can form snakelike bending patterns within the pipe, a special test apparatus at Lenox is being used to push the cable section at both ends to make it bend in a similar fashion 30,000 times, which is deemed equivalent to 80 years of service. The cable sample has survived 20,000 bends without damage to the insulation, and testing is continuing.

"These tests augment each other, and so far the results indicate that the cable has suffered very little deterioration over the years," said Steve Eckroad, program manager for underground transmission. "This information, combined with previous insights from EPRI's long-standing program in this area, will help PSE&G become more confident that its remaining Anaconda cable is in good shape, assuming similar operating conditions. More broadly, this type of testing will enable utilities to selectively replace cables by prioritizing their work according to the operating conditions involved."

Landmark research on failure of new cables was performed at the former EPRI Yonkers EHV Testing Laboratory during the 1980s and led to the establishment of test procedures such as those used in the recent study of the aged cable at Lenox. "Because such comprehensive testing opportunities are rare, the results of this study on service-aged cable will contribute significantly to the information available to the industry in this critical area," said Eckroad. "This is particularly important at a time when new utility engineers may face potential problems with cables that are older than they are."

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Cleaning Tool Speeds Up Line Splicing

Efficient repair of downed transmission lines is often the key to quickly restoring electricity service after windstorms and other extreme weather. But creating new splices for broken conductors can be a meticulous and time-consuming process—a difficulty that is now yielding to EPRI development efforts.

Most high-voltage lines are composed of dozens of separate aluminum strands wrapped helix-fashion around a reinforcing steel core. To make a splice, the ends of the broken line are recut, carefully aligned, and pressed together inside barrel-like tubes called compression connectors. To ensure that the splice is electrically sound and long lasting, special care must be taken to clean the ends of the conductor before they are rejoined. In fact, manufacturers' suggested cleaning methods often involve unstranding the aluminum wires in the conductor, cleaning each strand individually, and rewinding the strands around the core after cleaning. Not only is this procedure time consuming, but it can cause damage to individual strands, potentially compromising the splice.

Working closely with seven member participants—American Transmission Company, Tennessee Valley Authority, Oncor Electric Delivery, Public Service Electric & Gas Company, CenterPoint Energy, East Kentucky Power Cooperative, and Southern Company—EPRI has developed a cleaning device that will reduce both the time and cost of conductor repairs and increase the quality of the resulting splices. The highly portable tool, built by contractor EDM International, cleans the conductor effectively without the need for unstranding.

The process is quite simple. After the conductor end is inserted into the tool, which holds a detergent-like cleaning solution developed by Secat Inc., the solution is vibrated at a high frequency, causing it to migrate between the conductor strands. "The process is similar in concept to the ultrasonic process commonly used to clean jewelry," said EPRI department director Andrew Phillips. "Cleaning efficacy was confirmed through inspections with a scanning electron microscope, and splices underwent months of severe mechanical and electrical testing on a 120-foot test rig at our Charlotte facility. From everything we've seen, this cleaning tool will allow line workers to produce superior splices at a fraction of the traditional time and cost."

Southern Company, one of the tool's development sponsors, recently had a chance to prove him right during a restoration effort at subsidiary Georgia Power's Plant Bowen in Cartersville, Georgia. A tornado had taken down six transmission structures on several of the plant's 500-kV feeders, requiring 80 to 90 conductor cleanings as the lines were restrung over two weeks of repair. It would have taken 30–45 minutes to clean each conductor by using the manufacturer's recommended method. With the new tool, Georgia Power linemen were able to do each cleaning in just 6 minutes. Even conservative estimates put the time saved at around 32 hours—a tremendous advantage in a sprint to restore service.

One of the standout results of this demonstration was the cleaner's ease of use. According to EPRI's John Kile, who assisted with the Plant Bowen repairs, "The tool proved to be a device you could learn to use quickly and put to work immediately with minimal expert guidance. It's compact enough to use wherever the repair is most efficiently handled—on the ground or, in the case of dead-end connections, from up in a bucket. The repair team adapted to it quickly, and it performed exactly as it was developed to do." Southern Company's Alan Holloman was also impressed: "The crew was amazed at how thoroughly the tool cleaned each conductor," he said. "It did a superb job."

The success of the device stems largely from the development project's collaborative approach, in which member participants helped define the practical issues early on and made recommendations throughout the three-year development process. "Utilities have been in search of a tool like this for some time," said Phillips. "The research project was the result of our combined expertise and is an excellent example of the value of collaboration." A video that describes the conductor cleaning tool in detail and demonstrates its use is available on request.

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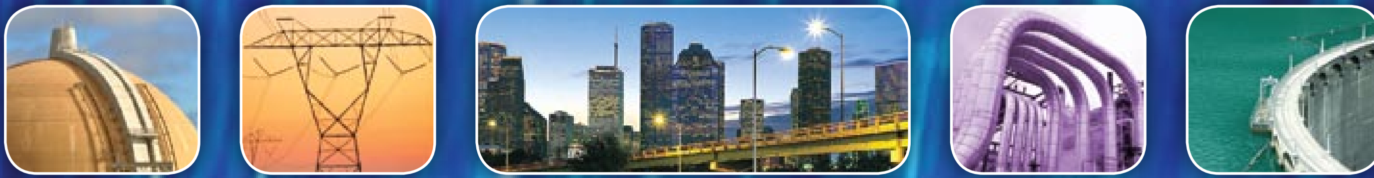

EPRI Guidelines Zero In on Fuel Failures

While wind and solar power often capture the headlines, nuclear power still offers the world its most economical and reliable choice for low-carbon electricity. But increasing the role of nuclear power requires convincing the public that nuclear power is safe.

One of the areas with the potential to impact public perception is fuel reliability. While unplanned shutdowns to replace failed fuel can cost in the tens of millions of dollars, the bigger cost is in terms of public perception—even when there is no danger to the public.

"Utilities are making significant investments to improve fuel reliability because of the strong desire to operate failure-free, even when the economics are less than compelling," said Kurt Edsinger, manager of EPRI's Fuel Reliability program. "Even though there is no public safety risk from a fuel failure (because of multiple containment barriers), it doesn't sound good. With a number of U.S. utilities entering the licensing process to build the next generation of nuclear plants, the stakes are high."

To address both the real impact of fuel failures and their negative perceptions, the utilities and EPRI have joined forces with the Institute of Nuclear Power Operations (INPO), nuclear fuel suppliers, the Nuclear Energy Institute (NEI), and others to eliminate fuel failures by 2010.

"It is a lofty goal, particularly when you look at the failure statistics we are attempting to improve: more than 99.999% of rods currently operate to end of their lives without issue," said Edsinger.

Fuel failures—breaches in the fuel rod cladding that allow the coolant to come into direct contact with the fuel—have generally been declining over the years. The failure rate for nuclear fuel assemblies in boiling water reactors (BWRs) is currently fewer than five failures per year, with more than 2 million fuel rods operating in 35 BWRs.

Pressurized water reactors (PWRs) present a more challenging story. PWRs are certainly experiencing fewer failures than they did 20 years ago, but the rate in recent years has continued to average around 50 failures per year. Although there are 69 PWRs in the United States, these failures are often concentrated in 10 to 20 reactors in a given year.

About three-fourths of PWR failures are caused by grid-to-rod fretting, which occurs when fuel assembly vibration, generally between the fuel rod and the spacer grid, wears a hole through the fuel cladding. Other leading causes are pellet-cladding interaction (a form of stress corrosion cracking), crud, corrosion, debris, and fabrication defects.

Failures in both BWRs and PWRs can be expensive. If a plant that experiences fuel failure can continue operating until the next scheduled outage, the cost may be only in the hundreds of thousands of dollars. If there are multiple failures requiring plant shutdown for large-scale rod replacement, the cost can jump to more than $50 million. To address these issues and the larger goal of zero failures by 2010, utility executives backed a plan to develop and implement fuel reliability guidelines for plant operators.

"EPRI has published a lot of research reports on the subject with detailed technical information," said Edsinger. "The guidelines took all that information, as well as information from other sources, and rolled it up into focused documents that operators can act upon without having to be Ph.D.s in multiple technical disciplines."

The new guidelines cover five areas: fuel surveillance and inspection, PWR fuel-cladding corrosion and crud, BWR fuel-cladding corrosion and crud, grid-to-rod fretting, and pellet-cladding interaction. More than 70 utility experts and 26 vendor experts helped develop the documents, along with experts from EPRI, INPO, and the NEI. More than 200 people from all U.S. nuclear utilities and five international utilities reviewed the guidelines to ensure their accuracy and relevance to fuel reliability issues. Though the initiative specifically targets U.S. nuclear plants, the underlying research results are applicable to all BWRs and PWRs.

The first four guidelines are now available, with the final one—on pellet-cladding interaction—scheduled to be released by the end of this year. Fuel reliability guidelines follow the industry protocol for implementation, where the most important recommendations are identified as "mandatory" or "needed," and others are identified as "good practices."

"All of the U.S. nuclear utilities have voluntarily committed to follow all mandatory and needed recommendations," said Edsinger, "and they are currently incorporating these recommendations into their plant-specific procedures. A number of the good practices will also be incorporated."

Following the guidelines will greatly reduce the incidence of fuel failure, but to completely eliminate failures will require minute attention to detail. "A bristle from a wire brush used to clean up a weld can get into the coolant, lodge in the spacer grid, and wear through the fuel rod cladding," Edsinger said. "That small, seemingly harmless piece of material can bring your plant down."

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REPORTS & SOFTWARE

Key deliverables now available

The following is a small selection of items recently published by EPRI. To view complete lists of your company-funded research reports, updates, software, training announcements, and other program deliverables, log in at www.epri.com and look under My Research Areas.

Fossil Plant High-Energy Piping Damage: Theory and Practice, Volumes 1–3 (1012201, 1015505, and 1016212)
To prevent the failure of high-energy piping, utilities need information on common failure paths and mitigation tools. EPRI's three-volume report provides a summary of the design, fabrication, failure mechanisms, inspection techniques, and condition assessment of piping systems. Volume 1, *Piping Fundamentals,* is an overview of piping design and fabrication. Volumes 2 and 3, *Performance of Steam Piping* and *Performance of Water Piping,* focus on the distinctive characteristics of the two piping types.

EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Design Handbook for Fossil-Fueled Electric Generating Stations (1014942)
Operations and maintenance personnel in fossil-fueled power plants perform physically strenuous tasks that can result in musculoskeletal disorders such as carpal tunnel syndrome or back and shoulder pain. This handbook provides guidance for applying ergonomics principles to the design of new fossil-fueled generating stations. Companies that have applied these guidelines when designing new facilities report increased worker productivity and reduced injury rates, which translate into lower operations and maintenance costs.

I&C Obsolescence Management Strategy: Pilot Study and Lessons Learned (1015083)
Modern digital technology promises to simplify nuclear plant instrumentation and control (I&C) architecture, reduce exposure to obsolescence risk, and streamline routine maintenance tasks. Because of resource constraints, however, I&C modernization is likely to follow a staged approach. EPRI developed a methodology for prioritizing, planning, and deploying individual projects within resource constraints. To validate the approach, EPRI worked with Exelon to update and refine the I&C obsolescence management strategy for their boiling water reactor fleet.

Field Guide: Visual Inspection of Porcelain and Glass Disc Insulators (1015530)
This EPRI visual guide, one of a series of field guides designed to support inspection and assessment of transmission components, is devoted to the subject of porcelain and glass disc insulators. The guide is conveniently organized and deals with each technology separately. Intended for practical use, the guide is ring-bound and sized to fit in a pocket. Full-color photographs support visual evaluation of the range of conditions likely to be encountered in the field.

Materials Reliability Program: Inspection Data Survey Report—MRP-219, Revision 1 (1016599)
Inspection data collected during nuclear plant outages can provide information to guide subsequent inspections and mitigation activities. This report summarizes the status of currently installed Alloy 600/82/182 components in the U.S. pressurized water reactor fleet. The data provided will allow utilities to quickly review flaw indication and failure experience, informing mitigation and inspection activities as well as outage contingency planning. The report also may be used as a resource for prioritizing nuclear-related research projects.

Demonstration of Decision Tool for Screening Eight Distribution Poles (1016803)
Replacing distribution poles requires making challenging decisions on pole types and materials to balance safety, reliability, and environmental and economic factors. This study demonstrated the use of EPRI's Poles Decision Tool (PDT) to evaluate eight poles according to 26 criteria that measure engineering technical performance, life-cycle cost/economics, and environmental profile. The demonstration showed the PDT to be a simple, viable tool that utilities can use to evaluate a wide variety of pole types, with criteria weighting factors that can be customized for specific regional conditions. The PDT can be widely applied throughout the electric utility industry.

Advanced Coal Power Systems with CO_2 Capture: EPRI's CoalFleet for Tomorrow Vision (1016877)
New technologies and methods are under development for reducing emissions of carbon dioxide (CO_2) from coal-fired power generation. This report is a concise primer on the status of combustion- and gasification-based advanced power technologies, opportunities for increased power generation efficiency, state-of-the-art emissions controls, and technologies for CO_2 capture and storage. The report also outlines the advanced RD&D required for critical-path CO_2-reducing technologies. With the primer, utilities can better understand the direction of advanced research and learn about collaboration opportunities that will support their own generation planning.

WIRED IN

Perspectives on electricity

Why We Work Together

From rapid response in a critical situation to long-term sustainability, Eskom's experience sheds light on the value of collaboration.

Dr. Steve Lennon
Managing Director, Corporate Services Division
Eskom Holdings Limited, South Africa

As the primary supplier of electrical energy in South Africa and power provider to neighboring states, Eskom has recently faced an unprecedented combination of challenges. Early in 2008, the electricity demand in South Africa exceeded the available supply, resulting in forced, planned load shedding across the whole country—a situation no utility wants to be in. The situation became so severe that on 24 January, the Eskom System Operator warned of a possible system collapse, and Eskom requested all its customers to make their processes safe. This had a significant effect on industry, as mines had to evacuate their underground workers and large industrial processes had to be shut down. More than 4,000 megawatts (MW) was being shed on a rotational basis throughout the country. Fortunately the system did not collapse, but Eskom's image had been undermined, along with confidence in South Africa's economy.

Eskom must manage many concurrent challenges as it sets about recovering from this situation. These include managing security of supply with a small reserve margin (~6%); maintaining the existing generation fleet to ensure high availability; balancing investment decisions for new plant with social, economic, and environmental pressures; accelerating a new build program to commission in excess of 14,000 MW by 2014; returning mothballed power plants to service; strengthening transmission and distribution networks; routing new transmission lines through constrained corridors; improving stakeholder communication and boosting industry confidence; financing capital requirements in a time of volatile financial markets; addressing emerging environmental legislation; building our workforce skills in the face of global shortages; . . . the list goes on. These issues are familiar to the electric power industry worldwide, but the extent of Eskom's challenges in a short period has put a high strain on its resources.

These challenges have only reinforced the importance of the associations Eskom has developed over many years with international organizations. In particular in the current year, the ability to draw on expertise from around the world has helped us make rapid and difficult decisions in implementing a recovery program. Eskom required a very rapid response in assessing the criticality of its system and in prioritizing a plan of action. EPRI provided the necessary expertise to help assess the situation and provided recommendations that have now been implemented. The process is ongoing, and the Eskom and EPRI partnership continues to make a positive contribution to our operations.

At the same time, we recognize that long-term sustainability is a critical driver behind our business. In this innovation space, the importance of diverse research and development support becomes clear. I can think of several areas where EPRI R&D is helping Eskom address its challenges:

- a clean coal technologies roadmap
- energy planning training
- equipment reliability assessment support
- an integrated defense plan against major grid disturbances
- loss reduction on distribution and transmission systems
- application of voltage reduction techniques to ease demand and energy consumption in the distribution system
- input into an assessment of how to accelerate the build program

Eskom has had an active process for transferring the research results and technology from EPRI into the organization. This is particularly important to ensure information is readily available to staff. Training programs run by EPRI are a primary method for this technology transfer and have proved invaluable. I must stress that this is also a two-way street: Eskom has developed technologies in its business which can benefit the power sector globally. We actively promote the inclusion of these technologies into EPRI's program.

I am pleased to report that Eskom performed exceptionally well over the winter, South Africa's highest demand period, without any further load shedding. It has not been easy, but through staff commitment and support from many quarters, we have provided a continuous supply despite our small reserve margin. We owe a portion of this success to the sharing and transfer of knowledge that has come from all over the world. The value of working together in research and development—and in transferring the knowledge—has never been made more clear than in South Africa.

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