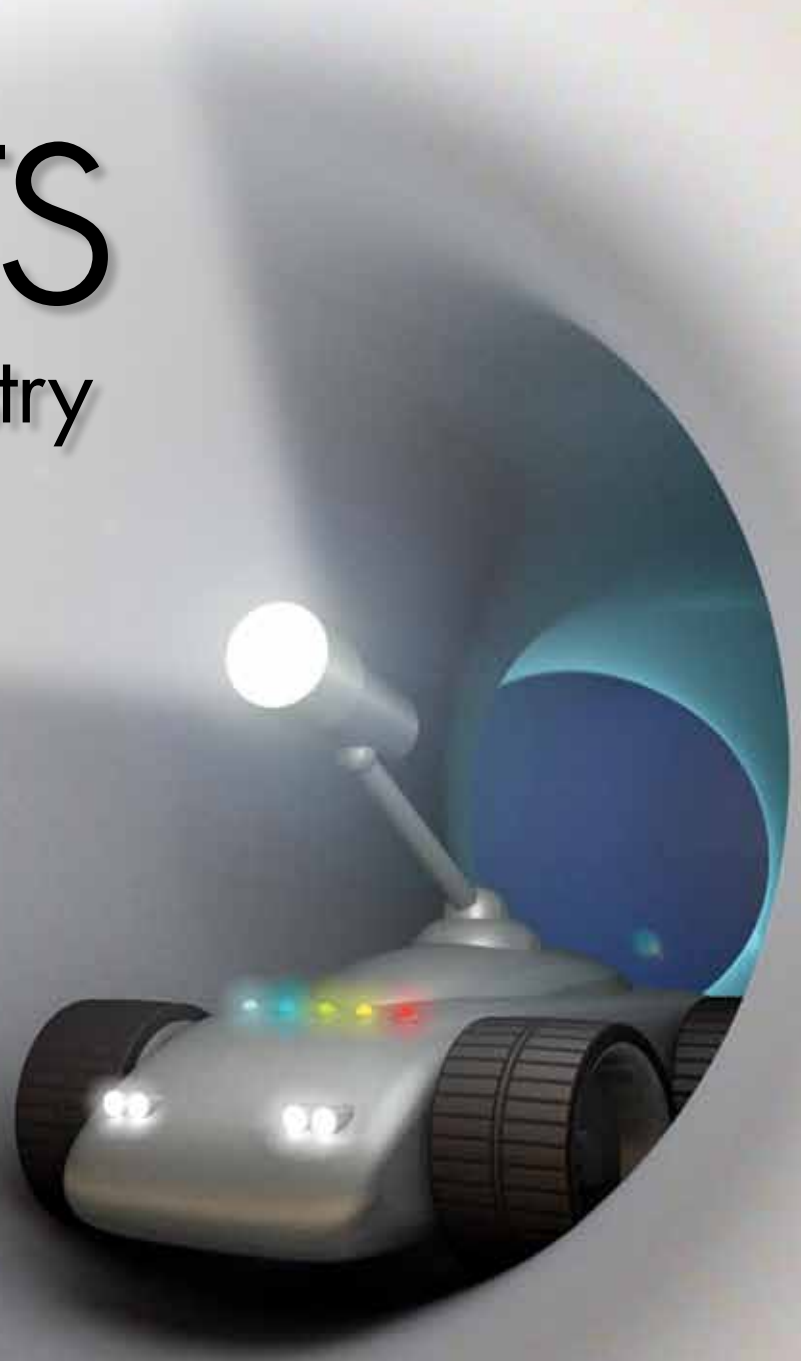
WINTER 2011

EPRI JOURNAL

ELECTRIC POWER RESEARCH INSTITUTE

Robots for the Power Industry



ALSO IN THIS ISSUE:

Power Companies Face Uncertainty over Environmental Rules

Consumers' Perceptions of Plug-In Vehicles

Thought Leadership: Driving Applied Innovation

ELECTRIC POWER
RESEARCH INSTITUTE

The Electric Power Research Institute, Inc. (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, 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 percent 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.

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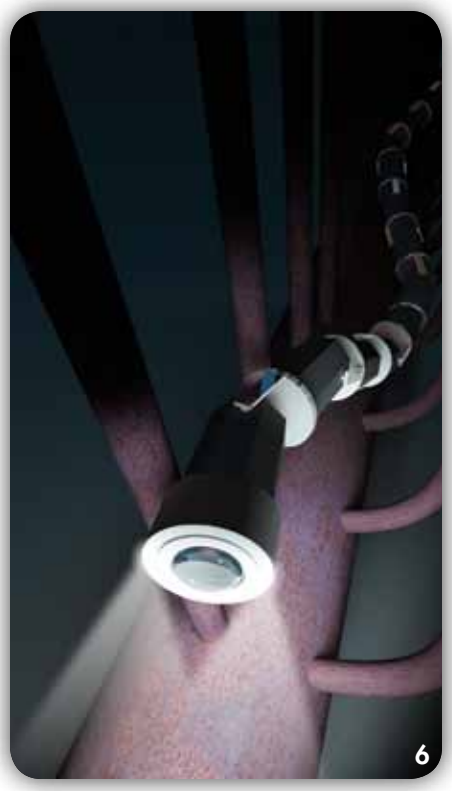

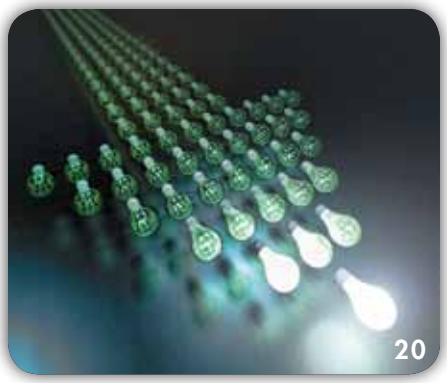

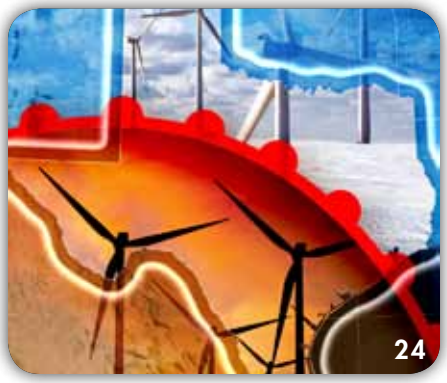

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VIEWPOINT

by Mike Howard, President and CEO, EPRI

Shaping the Future—and the World—of Electricity

The electricity sector looks very different in Asia, Africa, and Europe. In 2011, I met with electricity sector leaders on these continents to explore ways to sustain and enhance collaborative research, development, and demonstration (RD&D). Although cultural, geographical, and political differences are readily apparent from country to country, we should build collaborative RD&D on their diverse perspectives, experience, and strengths.

For example, in Asia I see particular urgency in developing the full portfolio of electric generating technologies, necessitated by rapid economic and population growth. Asian leaders are reluctant to eliminate any options, resulting in aggressive deployment of nuclear, fossil, and renewable generation technologies.

Consequently, the need is apparent in Asia to move toward near-zero emissions for fossil-fueled generation. It's common to read that China is building more than 1,000 megawatts, or "the equivalent of two coal-fired power plants," every month. And while it's difficult to pinpoint precise numbers, the International Energy Agency points out that China is clearly where the action is for building new coal-fired power generation, including advanced, higher-efficiency technologies. With China's rapid growth, it's likely it will emerge as leader in more efficient, cleaner coal technologies, including ultra-supercritical coal plants and carbon capture and sequestration.

China urgently needs transmission lines to move bulk power to its rapidly growing and industrializing cities. I am impressed by their initiative in building 1,000-kilovolt (kV) transmission lines. For those of us accustomed to 765-kV lines, the Chinese initiative can provide important insights and lessons learned, whether we're building new power grids or modernizing existing grids.

South Africa is addressing two critical imperatives simultaneously: bringing more generation on-line, while conserving every gallon of water possible. Worldwide, about 1 billion people live in desert climates, and there is much to learn from this arid

country as it tackles these twin imperatives. It has also showcased energy-efficient and demand-side technologies to meet growing demand.

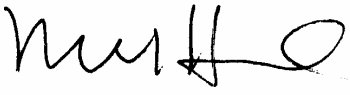
Europe and North America rely on mature technologies and infrastructure. We see more money and effort being spent on their long-term operation and on making them more productive and efficient. It is vital to their safe, reliable, and economical operation that we share lessons learned on operating aging assets. To this end, the Materials Aging Institute serves as a trailblazing example, with funding from Electricité de France (EDF), Tokyo Electric Power Company, Kansai Electric Power Company, China Guangdong Nuclear Power Company, and EPRI.

Spain and Ireland are leading the way for integrating variable wind resources. In EPRI's Smart Grid Demonstration Project, EDF and Ireland's Electricity Supply Board bring European expertise, results, and perspectives to assess how new resources such as demand response and electric vehicles can help to integrate variable renewable resources while improving grid reliability.

Beyond national boundaries, EPRI's R&D roadmapping framework is focusing on overarching strategic issues that look beyond traditional technological or organizational boundaries to drive R&D. This includes an array of strategic issues that touch on technology, operations, and environment, including:

- Long-term operation of assets
- Near-zero emissions
- Water resources management
- Smart grid
- Energy efficiency
- Renewable resources and integration

Meaningful innovation depends on our thinking, imagining, and working collaboratively across all boundaries—in our professions, our industries, and our countries. Together, innovation and collaboration will increasingly shape the world of electricity.



Michael W. Howard
President and Chief Executive Officer

From the International Energy Agency 2010 World Energy Outlook 2010–2035 (the "New Policies Scenario")

World primary demand for energy increases by one-third. World electricity demand grows by an average 2.2% per year, with more than 80% of growth coming in countries that are not part of the OECD (Organization for Economic Co-operation and Development).

An average of $1.5 trillion per year will be required for energy infrastructure from 2011 to 2035, two-thirds in non-OECD countries. The power sector claims nearly $17 trillion of the total investment.

Some 5,900 gross gigawatts of generation capacity will be added.

Investment in generation shifts to low-carbon sources, primarily nuclear and renewable, reducing fossil generation's share from 68% to 55%. The shift to low-carbon technologies is particularly marked in the OECD.

Renewable technologies, led by hydropower and wind, account for half of new capacity to meet growing demand. Renewable energy grows faster than other energy forms in relative terms, but in absolute terms, total supply is still not close to that of any single fossil fuel in 2035.

Nuclear generation grows by about 70%, led by China, Korea, and India, although its overall share increases "marginally," with 360 gigawatts of new capacity combined with life extension for existing plants.

Stronger uptake of existing clean coal technologies and carbon capture and storage could boost the long-term prospects for coal use. If the average efficiency of all coal-fired power plants were 5% higher than in the New Policies Scenario in 2035, such an accelerated move away from the least efficient combustion technologies would lower CO_2 emissions from the power sector by 8% and reduce local air pollution.

SHAPING THE FUTURE

Innovative approaches to upcoming challenges

Concentrating Photovoltaics Show Promise for Utility-Scale Generation

Unlike the flat-plate silicon panels often seen on rooftops, concentrating photovoltaic (CPV) systems convert light into electricity by using lenses or mirrors to focus a large area of sunlight onto a small square of high-efficiency solar cell material. By employing advanced, multi-junction cells that can convert broader portions of the light spectrum to electrical energy, high-concentration CPV systems have demonstrated substantially higher efficiencies than the 30% theoretical limit of conventional, single-junction solar cells. Laboratory efficiencies have already exceeded 40%, and researchers expect an advance to 45%–50% in commercial cells, perhaps as early as 2020.

While flat-plate silicon arrays are likely to remain dominant in rooftop applications, EPRI has concluded that CPV is ready to enter commercial contention as a utility-scale option in the best solar locations.

Photo courtesy of Solar Technology Acceleration Center (SolarTAC). © All rights reserved.

Technical Advantages

CPV systems are currently more expensive than flat-plate systems, but they hold several potential cost and performance advantages that are expected to be realized through continued R&D. Because they concentrate a tremendous amount of light—upward of 1,000 suns—on a chip perhaps just a square centimeter in area, CPV systems require only small amounts of expensive photo-active cell material. The major costs for CPV systems are in the balance-of-system components, such as supports, lenses, and tracking systems, made of abundantly available commodities, such as aluminum, steel, glass, and acrylic plastic. As a result, CPV systems can tap economies of scale to bring down costs, using standard high-volume production techniques and adapting existing manufacturing lines.

Multi-junction cells also experience far less degradation under high-heat conditions than silicon-based cells, leading to longer cell life and superior performance on hot days. CPV's two-axis sun-tracking systems carry advantages as well, offering higher capacity factors than nontracking flat-plate systems and higher afternoon energy capture to better serve typical load shapes. CPV systems can use passive air cooling, which makes them not only cheaper to manufacture but also less expensive to maintain than actively cooled systems, which require fans or water. Because they need no water for cooling, they are naturally well suited for the best solar locations—which typically have high direct irradiance but scarce water resources—and for environmentally sensitive areas.

Despite these technical and operational advantages, the case for widespread CPV commercialization will come down to economics. EPRI believes that costs will have to be reduced from the current $3.50–$5 per watt to $1–$2 per watt for the technology to compete successfully with other solar and renewable options. Meanwhile, prices will need to drop further from recently reported project prices of 11¢–14¢/kWh. (EPRI believes these prices do not represent levelized cost of energy because they likely include loss taking.) Government incentives may help the segment inch closer to these cost goals, but to truly unleash terawatt-scale production and usage, CPV companies will need to prove to financiers, project owners, and utilities in the near term that their systems are worth the investment. Still, the technology development community is optimistic about CPV's prospects, with the international CPV Consortium projecting an impressive cumulative capacity build-out to roughly 4,600 megawatts by 2015—an increase several orders of magnitude from today's installed base of approximately 20 MW. In the last year alone, utilities have signed contracts for over 300 MW of CPV projects; they are now awaiting regulatory approval and financing.

Research Needs

In addition to continued technical work to improve efficiency and reduce costs, new standards will be required that clarify performance metrics and allow meaningful cost comparisons.

A dearth of objective field testing has also been a primary obstacle to CPV market development and growth. In response, EPRI has initiated a three-year program to independently field-test several early-stage and near-commercial CPV technologies at the Solar Technology Acceleration Center (SolarTAC) in Aurora, Colorado. Initial field tests will examine the technology's

potential for modular deployment from distributed to central-station scales, expected operational profiles for a broad range of climates, and reliability and availability in a real-world setting. Among the areas of field examination will be system installation, commissioning, performance, reliability, and operation and maintenance requirements.

It is hoped that satisfactory operating results—captured via extensive collection of performance and reliability data—will provide valuable corroboration to utilities and financial institutions of CPV's readiness and suitability for utility-scale commercial applications.

For more information, contact Nadav Enbar, nenbar@epri.com, 303.551.5208.

Shale Gas Alters Market Fundamentals

Natural gas trapped in the fine-grained sedimentary rock known as *shale* is extracted by fracturing the rock to increase its permeability and release the gas. Drilling innovations and the technology for fracturing shale have advanced so rapidly and dropped production costs so dramatically that today shale gas accounts for more than 20% of the natural gas supply in the United States, a proportion that the Department of Energy expects will increase to 47% by 2035. Known economic shale resources are large, and additional resources continue to be discovered; they are now found widely throughout the United States and in many other parts of the world.

The shale phenomenon was enabled by a combination of rising gas prices in the early 2000s, rapid technology development, and intense entrepreneurial activity—all of which spurred shale exploration and testing. As corporations have invested in shale resources or have bought shale developers in their entirety, the cumulative value of U.S. shale transactions has grown tenfold in the last five years, from roughly $10 billion in 2006 to $100 billion today.

Price/Production Disconnect

According to EPRI analysis, shale gas has altered the underlying supply fundamentals of natural gas so rapidly that market equilibrium has not yet been reached. With the addition of nearly 700 trillion cubic feet (Tcf) of shale gas potential to the natural gas resource base, estimated U.S. reserves plus resources jumped more than 40% in the last few years (from 1,532 Tcf in 2006 to 2,172 Tcf in 2010). One result of the new potential is that forecasts have had to be rewritten. The 2020 gas production now projected is 2.8 Tcf/year higher than that projected by highly reliable forecasts made just four years ago in 2007. Given the new competition from shale gas, forecasts for liquefied natural gas (LNG) imports by 2020 have fallen by more than 80%, and terminal owners have actually begun to regear to be able to *export* LNG.

Most surprisingly to resource economists, natural gas prices and production have become decoupled, and economic equilibrium has not yet been reestablished. Prices collapsed in 2008 from $8/million British thermal units (Btu) to $4/million Btu as a result of the financial/economic crisis and competitive forces unleashed by shale gas development. Prices continued to fall into 2009, driving the rig count for traditional supplies to about 40% of its peak, while aggregate gas production continued to climb. Under normal circumstances, production would be cut back with such price declines. Nevertheless, following a mid-decade slump, gas production has increased steadily from around 50 billion cubic feet (Bcf)/day in 2005 to an estimated 62 Bcf/day in 2011.

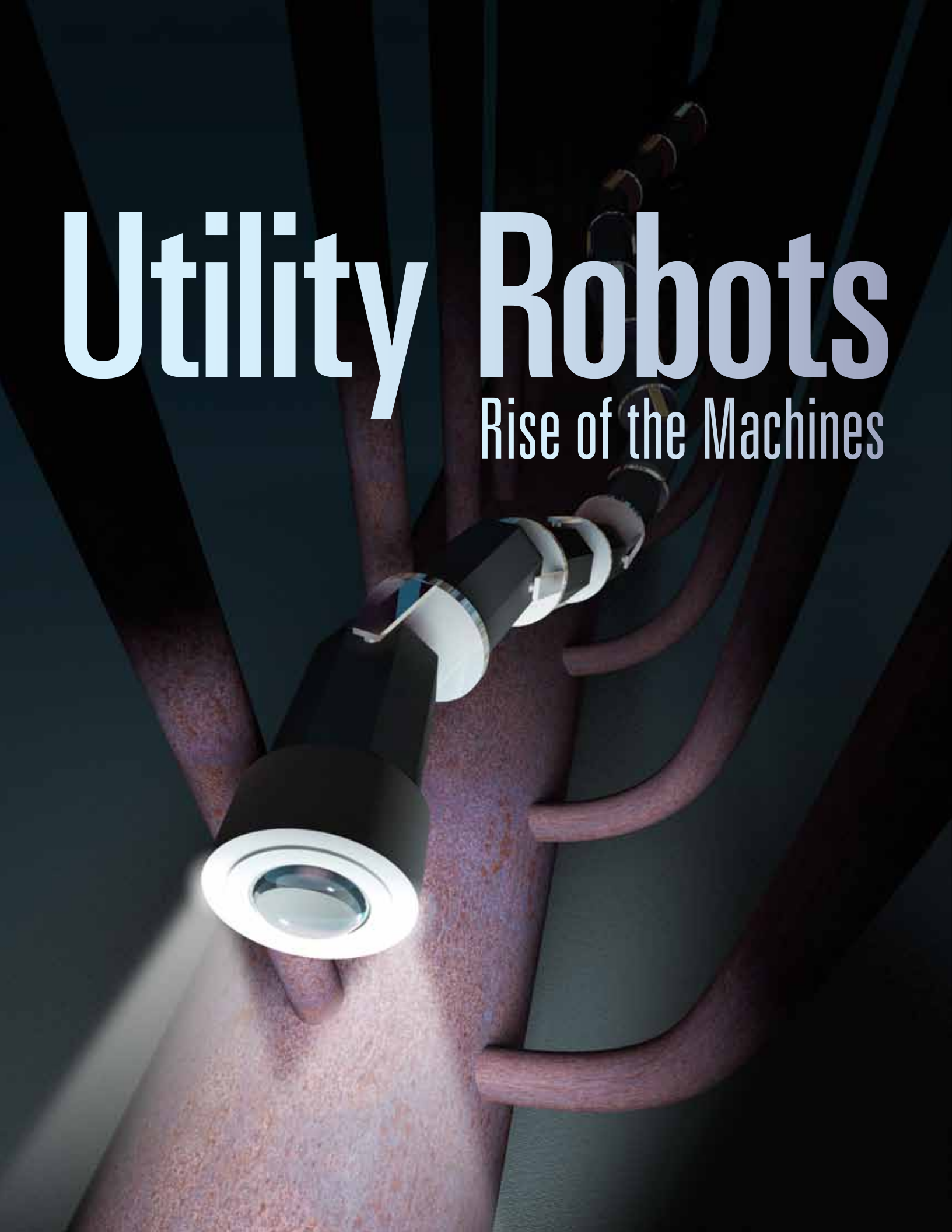
Gas producers, the U.S. Energy Information Administration, and EPRI have all described the current market environment as a temporary anomaly. Gas remains abundant and underpriced. Correction will come in time, and prices will inevitably have to rise to reach sustainable levels, according to resource economists; however, there is considerable debate about how soon this might occur.

Power System Impacts

In the power industry, lower gas prices have not only reduced electricity prices in the short term, but also have accelerated the long-term displacement of coal generation by natural gas combined-cycle generation. Coal switching became pervasive in 2009 and has increased since, especially in areas with higher-cost coal generation, including the Southeast, the Northeast, and the mid-Atlantic region. Along with investor assumptions of an abundant future gas supply related to shale development, rising coal prices have added momentum to the switchover to gas. Companies have responded to higher coal prices by cycling or shutting down coal units and speeding the path to unit retirement.

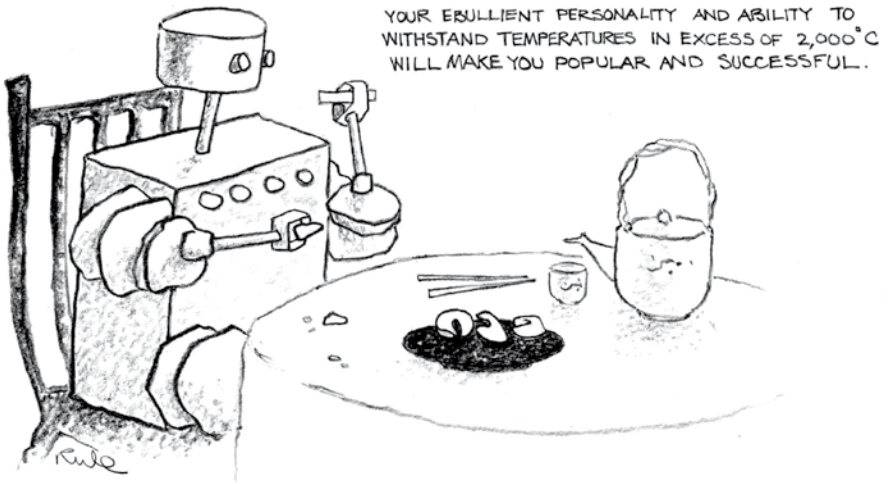
Such action reflects industry confidence that shale gas has arrived as a reliable and abundant resource. Gas prices are expected to move up when today's anomalies come to an end, but the underlying supply fundamentals have put the natural gas market into a new, generally lower-cost regime that will rely as much on estimated potential shale gas resources as on proven reserves of conventional natural gas resources.

For more information, contact Jeremy Platt, jplatt@epri.com, 650.855.2179.


Utility Robots
Rise of the Machines

THE STORY IN BRIEF

Robots are the power industry's allies for complex inspection and data collecting missions.



They don't look like the Terminator or come from the Forbidden Planet. But robots are becoming important allies to the power industry, performing tasks that are too risky, remote, or complex for humans to handle efficiently. The industry is starting to pay attention to the possibilities: in October 2010, the first International Conference on Applied Robotics for the Power Industry brought together robotics experts and power company representatives from 22 countries to facilitate the development of suitable machines.

EPRI has long recognized that robots can perform critical functions and has been developing robots for power plant and high-voltage environments since the 1970s. One early power line robot, TOMCAT (Teleoperator for Operations, Maintenance, and Construction using Advanced Technology), featured a large remotely operated arm for work on live transmission wires.

EPRI designed TOMCAT to be an all-purpose machine, but robotics trends now call for smaller equipment to perform specific functions. EPRI's current work covers a wide range of applications and makes use of the knowledge of research and industry partners to investigate promising technologies while lowering development costs. Today's projects put robots inside major plant components, on suburban streets, and on high-voltage transmission lines.

Taking the Heat

Robots make good detectives, and they are particularly adept at performing work that involves squeezing into tight spaces, such as the vertical and horizontal tubes of a heat recovery steam generator (HRSG). In a combined-cycle plant, these tubes transfer heat from the combustion turbine's exhaust gas to water flowing through the tubes to generate additional steam for electricity production.

The closely bundled tubes are typically 50–70 millimeters (2–2.75 inches) in diameter and extend 12–18 meters (40–60 feet) between the upper and lower headers. Physical limitations pose big challenges for close inspection. When the tubes perform poorly or fail altogether, the causes can be complex and difficult to uncover.

So inspection requires something flexible and agile. Accessing the tubes inside the bundle presents a particular challenge for nondestructive evaluation (NDE) because the ultrasonic and eddy-current equipment used to detect problems must be in contact with the tubes. Robots are good candidates, and a so-called "snake" robot has been developed to crawl around in the tight environment. EPRI is working with Carnegie Mellon University to improve the robot's agility, speed, and efficiency and to add capabilities to perform NDE.

The goal is to improve the robot's ability to inspect the hard-to-access center of the tube bundle. Designers also hope to be able to introduce the robot for a complete inspection through a single entry point in the HRSG header, avoiding the time and cost of cutting and closing multiple entries. Other modifications would allow the robot to climb vertical tubes more easily and to direct its inspection camera straight down the tube bundle.

The team plans to alter the robot's "gait" so that it can maneuver through different tube configurations and remain stable when encountering obstacles. To increase its range of motion and prolong its operation in the field, researchers are looking to reduce the weight of the robot's tether while adding other safety features. Over time, EPRI plans to add more NDE capabilities for a wider range of problems and solutions.

Seeing the Light

Light-emitting diode (LED) technologies use energy more efficiently than conventional lighting and promise a longer lifespan, resulting in lower operation and maintenance costs. Since 2009, EPRI has been conducting an LED energy-efficiency demonstration to assess the technology for street and area lighting.

EPRI designed a robot, called Scotty, to help researchers collect data from the 20-plus U.S. demonstration sites. Scotty takes precise measurements of light levels on the street so that researchers can determine, among other things, how much and how fast the light intensity deteriorates over time. It's not an easy job. Researchers want to collect photometric data near the ground and to do so in a precise grid. In

Scotty, a mobile light-measurement robot, performs accurate, timely, and repeatable measurements of LED light levels.

Ti, a transmission line inspection robot, can traverse 60 miles (96.6 km) of line at least twice a year, collecting high-fidelity information that utilities can act on in real time.

the past, researchers manually inspected the equipment, made light measurements, and recorded the data.

Scotty, a four-wheeled, remote-controlled robot, is proving to be a faster, more exacting surveyor. Guided by a global positioning system (GPS), Scotty traces designated paths, measures lighting levels, and transmits the readings to a remote computer five times per second. The robot completes a job in minutes rather than hours. It can measure all types of lighting, allowing direct comparisons of LED systems with more conventional options.

Thanks to Scotty's precision, researchers are making measurements at a 2-foot (0.6 m) spacing, providing much more detail than the conventional 10-foot (3.1 m) spacing. The robot also keeps human inspectors off the streets, where they may be exposed to speeding cars and other hazards.

Living the High(-Voltage) Life

Transmission lines present a substantial and expensive challenge for human inspection and maintenance. They stretch hundreds of miles, often through remote areas.

As the technology is refined, momentum is growing to use robotic inspection for transmission line components. In a survey conducted during last year's robotics conference for the power industry, 32% of the respondents said they used robots for live-line work, most often for replacing parts or cleaning insulators. Inspection and preventive maintenance applications could greatly increase the use of robots on the high wires.

EPRI is refining a prototype, called Ti, to develop an inspection robot that can reside permanently on a transmission network, traveling up to 40 miles (64.4 km) on a line in four months. The robot will then reposition itself on another wire or be moved by a line crew. Along the way, the robot will identify right-of-way encroachment and any vegetation that threatens the performance of the line, plus monitor and report problems with transmission line components.

EPRI researchers are now analyzing data from laboratory tests to improve Ti's design. The current prototype can run at up to 3 miles (4.8 km) per hour and inspect, on average, 15 segments of 138-kV line each day.

Ti incorporates high-definition infrared cameras and image-processing technology and can compare images taken at different times to track equipment deterioration well before failure. Researchers expect to add a light detecting and ranging (LIDAR) sensor to provide close measurements of the relative positions of the conductor, vegetation, and other structures. Ti's use of GPS technology enables utility operators to quickly pinpoint trouble spots.

Ti will also transmit data collected from sensors already installed along the transmission lines to check on the performance of insulators, conductors, and compression connectors. This use of sensors can be critical, particularly in regions that experience strong winds or frequent lightning.

Creating inspection robots for the nation's transmission network will continue to be a key focus. EPRI will unveil a new transmission robot at the Utility Products Conference and Exhibition in San Antonio, Texas, in January 2012.

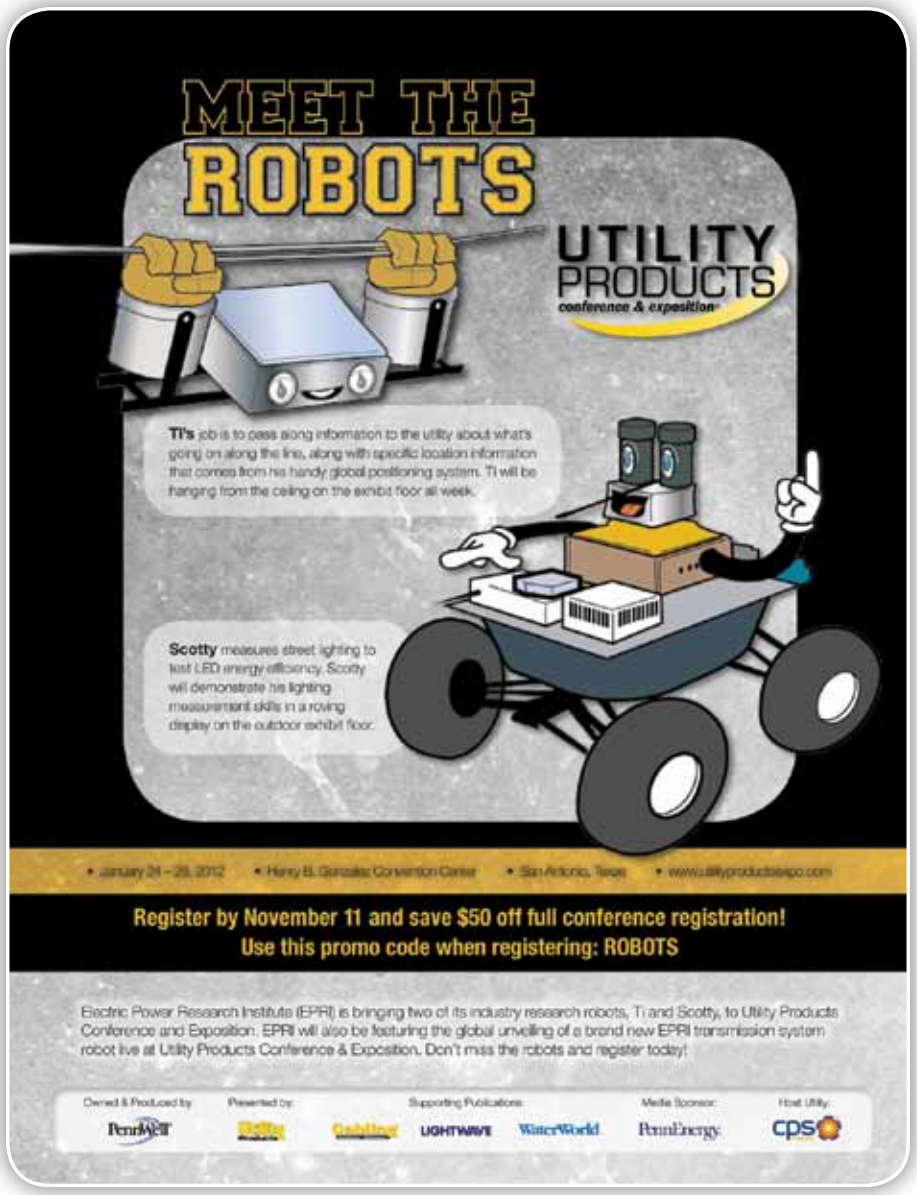
Nuclear Reactor Drain Line

The interior surfaces of carbon steel drain lines in a boiling water reactor (BWR) are susceptible to corrosion by the deoxygenated water that flows through the pipes. If not detected early enough, corrosion can thin pipe walls and cause failures that could lead to an unscheduled shutdown or other problems. EPRI is developing a series of robots to inspect and evaluate reactor drain lines for various BWR designs.

Drain line examination presents key challenges. The lines are surrounded by extensive hardware at the bottom of the reactor, making access difficult. Moreover, the configuration of drain lines and adjacent equipment differs by BWR plant design.

In 2007, EPRI conducted a field test to demonstrate the first robot's ability to remotely assess the wall thickness of a BWR drain line. The reactor's piping configuration was typical of BWR reactor Models 5 and 6. The robot used two rotating ultrasonic transducers to measure the thickness of the drain line pipe. Data analysis showed that the drain line was in good condition. Since then, three other reactors have deployed the same robot design to inspect drain lines.

A second-generation robot was designed for a drain line configuration typical of BWR Model 3 reactors. In these reactors, the drain line follows a complex path on top of an I-beam and through pieces of hardware, such as a control rod drive mechanism and in-core flux-monitoring tubes. The complexity of the operation prompted researchers to build a detailed, full-scale mockup of the piping configuration, including obstructions. Testing the robot



EPRI robots will receive star treatment at the Utility Products Conference and Exhibition in San Antonio in January 2012; two are pictured here in an advertisement.

on the mockup allowed engineers to fine-tune the robot, identify likely problems, and train the inspection team.

In 2011, after two years of development, the new robot was put to use during a reactor's planned maintenance shutdown. The EPRI–utility team encountered a navigation problem because the mockup did not correctly reflect a spacing gap, but after some modification, the robot completed its mission and provided the data necessary for the plant owner to certify that the drain line was in good operating condition.

Inspection of Concrete

EPRI is also designing a robot to facilitate the inspection of large concrete structures. The "concrete crawler" will have to be able to move over curved concrete wall surfaces, be rugged enough to withstand outdoor use, and run on a battery that can last three to four days. Why? Because the crawler will be checking large structures such as cooling towers, containments for nuclear reactors, and hydropower dams, said Maria Guimaraes, a project manager in EPRI's Nuclear Sector.

Currently, inspectors assess the integrity of such concrete structures with manually applied NDE equipment, using scaffolds that must be moved around the structure to gain access. As concrete structures age, the need for evaluation increases. "Right now, it takes a long time to inspect a cooling tower," Guimaraes noted. "With a robot, it could be safer, simpler, and less expensive."

The concrete crawler will carry test equipment and collect data for later analysis in the lab. Forty companies responded to a request for proposals for the concrete crawler projects this past summer. EPRI is evaluating the proposals and plans to conduct field tests next year.

This article was written by Ucilia Wang. Background information was provided by Andrew Phillips, aphillip@epri.com, 704.595.2728, and Maria Guimaraes, mguimaraes@epri.com, 704.595.2708.

Andrew Phillips is technical director of transmission and substations in the Power Delivery and Utilization Sector. Before joining EPRI in 1998, he worked at J.A. Jones Power Delivery as a lead researcher in the fields of insulation, aging equipment, and lightning. Prior to that, he performed research for the South African electric power industry at the University of the Witwatersrand. Phillips received B.S., M.S., and Ph.D. degrees in electrical engineering from the University of the Witwatersrand in Johannesburg, South Africa.

Maria Guimaraes is a project manager in EPRI's Nuclear Sector, specializing in the aging and inspection of concrete structures. Before joining EPRI in 2009, she worked for Aalborg Portland in Denmark, developing new cements that have reduced CO_2 emissions. Guimaraes holds a B.S. in civil engineering from the Universidad Nacional del Nordeste in Argentina, an M.S. in the same field from Newcastle University (UK), and a Ph.D. in civil and environmental engineering from the Georgia Institute of Technology.


AN ACT To provide for water pollution control activities in the Federal Security Agency; and for other purposes.
Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled
TITLE I—RESEARCH AND RELATED PROGRAMS
DECLARATION OF GOALS AND POLICY
Power Companies Face Uncertainty over Environmental Rules
The confluence of new environmental regulations expected in the next several years presents tough challenges for electricity generators—particularly those with coal-fired power stations.

THE STORY IN BRIEF

The confluence of new environmental regulations expected in the next several years presents tough challenges for electricity generators—particularly those with coal-fired power stations. EPRI studies have helped clarify the scientific issues and provided power companies with options for complying with more stringent environmental limits.

Over the next few years, electric power companies will face a host of new environmental regulations that will tighten existing limits on emissions of air pollutants and other waste streams and introduce restrictions on previously unregulated substances. Although each of these new rules has been developed independently of the others, all of them will likely take effect between now and roughly 2018. The confluence of these new regulations presents many challenges for electricity generators, particularly those with coal-fired power stations, which will be hit hardest by the new rules. "We saw all of this coming," said Bryan Hannegan, EPRI vice president, Environment and Renewables. "We just didn't see it all coming at the same time."

The Value of Good Data

EPRI research provides scientific data and information that policy makers, regulators, and power companies alike can use to inform the development of environmental rules and regulations. EPRI research ensures that the best possible data are available for use in developing the rules and can provide analyses of the estimated technology needs or operational requirements of any proposed rules. For example, for the effluent guidelines rule, EPRI will perform a review of the data quality obtained from a United States Environmental Protection Agency (EPA) survey of wastewater releases from power plants to help ensure that reporting by various facilities is done consistently and that results are interpreted correctly.

EPRI conducted similar studies of data collected on emissions of hazardous air pollutants, such as mercury and other air toxics. In addition to identifying several consistent data quality issues, EPRI has worked to identify correlations among multiple pollutants. This work may support simpler, more manageable standards than ones based on measuring each of the roughly 500 air toxics individually. It may be possible to monitor trace metals by measuring particulate matter, for example, or to use hydrochloric acid as a representative of all acid gases.

Other EPRI studies evaluate benefits and risks to human health or to ecosystems. For example, when proposing new regulations under Clean Water Act Section §316(b), the EPA initially had considered a retrofit requirement that would mandate the use of closed-cycle systems (cooling towers) to reduce the number of fish pulled in to cooling water intake structures. EPRI determined the cost of this measure to exceed $100 billion, while the monetized environmental benefits would be about $300 million. EPRI provided data showing that using alternative screening technologies and redesigned inlets could protect aquatic life just as well, if not better, for a fraction of the cost and achieve environmental benefits equivalent to those provided by cooling towers.

In addition, EPRI sponsors development and testing of new technologies, including pollution control measures, to help utilities comply with regulations. For example, EPRI's sorbent activation process uses coal byproducts as a source of activated carbon for capturing mercury emissions. This technology can help utilities lower costs by producing the needed activated carbon in the plant instead of purchasing it from outside sources and having it shipped to the plant.

What's a Utility to Do?

For many existing units, compliance will not be as simple as installing a better scrubber or a new piece of control equipment on the back end of the plant. Pollutants removed from one waste stream must go somewhere else. "If I am removing selenium from my air emissions to comply with the hazardous air pollutants rule, I don't want to run afoul of wastewater limits if the selenium suddenly ends up in my water," said Hannegan. "And if I pull it out of my water, it may wind up in my ash, where possible new coal ash restrictions may come into play." What may seem to be the best design for reducing one type of pollution today may prove less than optimal when the other rules are put into place. As a result, many companies are finding it difficult to determine the best ways to satisfy current laws and prepare for future limits while anticipating demand for generating capacity.

While addressing the new regulatory mix, utilities also need to prepare for demand growth in a slowly recovering economy in which it is difficult to predict when—or if—industrial and commercial demand will pick up. For the residential market, utilities are uncertain how much of the load will be offset by self-generation or energy-efficiency investments. Forecasting fuel prices is another complicating factor. Today's low natural gas prices present opportunities and risks to any utility that chooses to allocate its assets in gas-fired generation. Coal's low cost makes it an attractive fuel, even if expensive pollution

NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

WHAT IT GOVERNS
Oxides of nitrogen (NOx), oxides of sulfur (SOx), and particulate matter; also carbon monoxide, lead, and ozone

MAJOR CHANGES
Hourly limit for NOx added to previous annual average; hourly limit for SOx replaces annual and 24-hour averages; 24-hour limit lowered for fine particles

REASON FOR CHANGE
Normal review cycle specified in Clean Air Act

STATUS
Final

NAAQS SECONDARY STANDARDS

WHAT IT GOVERNS
Same as NAAQS primary standards

MAJOR CHANGES
Currently, the same as NAAQS primary standards, but subject to revision

REASON FOR CHANGE
"Public welfare;" reduce acid rain; protect animals, buildings, vegetation, and ecosystems vulnerable to acidic conditions

STATUS
Proposed

CROSS-STATE AIR POLLUTION RULE

WHAT IT GOVERNS
Same as NAAQS; affects most states in eastern half of U.S.

MAJOR CHANGES
Curbs emissions that can raise levels in downwind states

REASON FOR CHANGE
Result of 2008 lawsuit by states and environmental groups challenging 2005 EPA rule

STATUS
Final

CLEAN WATER ACT SECTION 316(b)

WHAT IT GOVERNS
Open-cycle cooling-water intake systems

MAJOR CHANGES
Impingement and entrainment standards for fish protection and for new units at existing facilities; technology equivalent to closed-cycle-cooling fish protection performance

REASON FOR CHANGE
Best technology available for minimizing adverse environmental impacts from cooling-water intake structures

STATUS
Proposed final rule due July 2012

controls are needed, but competition from natural gas and alternative energy sources can decrease the demand for coal, which could drive its price even lower. Renewable portfolio standards will also influence generation choices.

Potential greenhouse gas restrictions complicate the picture even more. As of this writing, the EPA has not yet presented a proposal for greenhouse gas emissions, and it has revealed little about its intentions. "The carbon dioxide rule is kind of a wild card," said Hannegan. "CO_2 is a fundamental byproduct of combustion, and current technologies for CO_2 capture are very expensive." Meanwhile, the other (non-CO_2) pollution controls have significant parasitic loads, which means more fuel, not less, must be consumed—and more CO_2 emitted—for the same generating capacity.

In the absence of certainty about how these environmental rules will evolve, some utilities have negotiated voluntary arrangements with state legislatures or with the EPA in which they agree to close certain plants and install new pollution controls on others, in exchange for being held harmless from any changes that may make the plants out of compliance when the proposed rules are finalized. This strategy could lead to the retirement of some coal plants that would otherwise have remained in service.

Changing Landscape

One thing seems certain: the generation fleet will change as a result of the new regulations. Smaller, older, and less efficient coal-fired generating plants will be closed because they are too expensive to bring into compliance, relative to other generation options. About 20 gigawatts of capacity has already been slated for retirement, resulting in economic impacts on supporting businesses and in surrounding communities.

> **"One thing seems certain: the generation fleet will change as a result of the new regulations."**
>
> *~ Bryan Hannegan*

COAL COMBUSTION RESIDUALS

WHAT IT GOVERNS
Coal ash

MAJOR CHANGES
Design and operation of landfills and surface impoundments to prevent spills of coal ash slurries or leaching of toxic metals

REASON FOR CHANGE
Nonhazardous classification under review following 2008 impoundment failure in Kingston, TN

STATUS
Proposed final rule due date to be determined

WATER EFFLUENT GUIDELINES

WHAT IT GOVERNS
Water pollution, primarily from flue gas desulfurization systems

MAJOR CHANGES
Undetermined

REASON FOR CHANGE
Rising levels of water pollutants due to increasing use of air pollution controls

STATUS
Data collection phase; proposal due in 2012, final rule in 2014

NEW SOURCE PERFORMANCE STANDARDS FOR POWER PLANT GREENHOUSE GAS EMISSIONS

WHAT IT GOVERNS
Carbon dioxide and other greenhouse gases

MAJOR CHANGES
Undetermined

REASON FOR CHANGE
Settlement of lawsuit by various states and environmental groups

STATUS
Proposal pending as of this writing; final rule due May 2012

HAZARDOUS AIR POLLUTANTS (HAPS)—MERCURY AND AIR TOXICS STANDARD

WHAT IT GOVERNS
Coal- and oil-fired power plant emissions of mercury and other toxics

MAJOR CHANGES
First national rule for maximum achievable control technology to reduce HAPs emissions; numerical limits for mercury, non-mercury trace metals, and acid gases

REASON FOR CHANGE
Court-ordered inclusion of electric generating units; EPA had previously concluded they could be excluded from Clean Air Act amendment

STATUS
Proposed final rule due November 2011

EPRI has developed a mathematical model of the nation's electricity system that can help utilities decide how to consolidate their coal fleets and plan for an optimal mix of generation technologies. The regional energy and economic model (Prism 2.0) incorporates regional economic data, existing capacities, investment opportunities, and projected fuel costs under a variety of regulatory and technology scenarios.

"A surprising thing for all of us when we did the math was that there was still a substantial role for coal in this country, even with these new rules on the horizon," said Hannegan. Coal—currently about half of the total generation mix—stays at about the same level until 2050 in the reference scenario, although other sources increase with rising energy demand. With a national clean energy standard in place, demand for coal and gas remains (but declines over the next 50 years), especially if new technologies are not adopted. If CO_2 is regulated, the model predicts that coal use drops quickly over the next 15 years unless capture and sequestration technologies become feasible.

The optimal generation mix varies across regions of the country, even with the same policies in place everywhere, because fuel resources are not uniformly distributed.

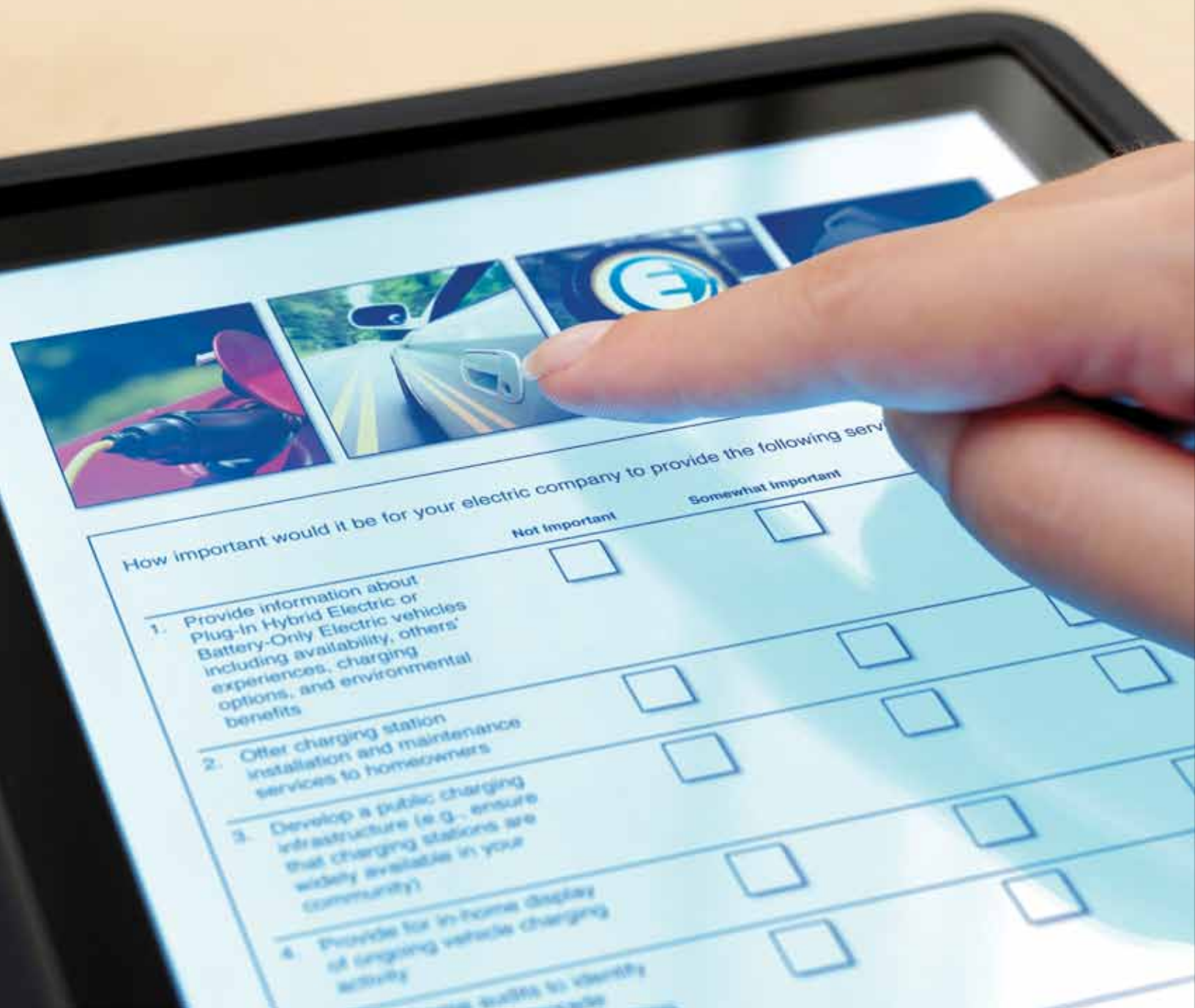
"That's one thing to keep in mind about all of these environmental rules," said Hannegan. "Because they are aligned with coal, they will have a disproportionate impact in places where coal makes up the bigger share of the generation mix.

This article was written by Cliff Lewis. Background information was provided by Bryan Hannegan, bhannegan@epri.com, 650.855.2459.

Bryan Hannegan is vice president, Environment and Renewables. Before joining EPRI in 2006, he served in a dual capacity as Chief of Staff for the White House Council on Environmental Quality (CEQ) and as acting Special Assistant to the President for Economic Policy. Between 1999 and 2003, he served as staff scientist for the U.S. Senate Committee on Energy and Natural Resources. Hannegan holds a B.S. in meteorology from the University of Oklahoma and two degrees from the University of California, Irvine: an M.S. in engineering and a Ph.D. in earth system science.

Electric Wheels

Plugging in to Consumers' Perceptions



THE STORY IN BRIEF

How will consumers react to the auto industry's rollout of electric vehicles, and how do they expect their power companies to be involved? New EPRI-developed surveys gather regional information on the public's interest, assumptions, wants, and needs.

Meet Sam. Sam is about to buy a car, but he doesn't know which one. He stands on the dealer's lot engaged in a host of complex calculations, examining alternatives and weighing the pros and cons of model, cost, fuel efficiency, reliability, and even color. These days Sam has another important choice: gas or electric?

With an electric vehicle, Sam must take into account even more variables: When and where will he charge the vehicle? How much will charging cost? Is he willing to pay a premium to own such a car?

In 2009, EPRI researchers undertook to gauge how Sam and other consumers view electric cars and what they expect of their electric utilities. Electric vehicles represent a tiny fraction of the vehicles on the road today, but Mark Duvall, director of EPRI's Electric Transportation Program, expects production to ramp up quickly. "By 2015," according to Duvall, "it's quite likely we'll have more than a million electrics on the road." As the number of electric vehicles grows, so will demand for power. For an industry accustomed to serving stationary customers, utilities are finding that vehicles present an entirely new set of challenges. "It's a different business," said Bernard Neenan, a technical executive at EPRI. "For the first time, our customers are mobile."

Consumer Survey

EPRI's Electric Transportation Program has long focused on understanding how electric vehicles will affect the power grid and how utilities will accommodate the added demand for power. In 2008, the program's members decided to incorporate another key component of the equation: electricity customers. To prepare for an influx of electric vehicles, utilities need to know when their customers will buy cars, what kinds of cars they will buy, and how those purchases will affect the way they use electricity.

Researchers developed an online survey to examine customers' perceptions of electric cars and the factors that influence electric car purchases. The survey builds on the findings of EPRI's 2001 national survey of electric vehicle interest, which focused on what consumers want from an electric vehicle. This time, members wanted a survey to help them understand how customers view the utility's role in electric transportation in their own service areas. "We know electric cars are not going to be adopted uniformly across the county—or even within a utility's service area," said Neenan, the project manager. "So it makes sense to gather information specific to the characteristics of the customers in that area."

As Neenan and his colleagues tested the survey to "work out the bugs," focus group discussions revealed a serious problem: consumers didn't understand the researchers' nomenclature. "They thought an electric car was a hybrid car or a hybrid car was an extended-range car," Neenan said. "That confusion would have been a disaster in the survey." To address this issue, the researchers added an educational component to outline the differences between standard gasoline vehicles, hybrid electric cars, plug-in hybrid electrics, and battery-only electric vehicles.

Electric Future

In July 2009, EPRI collaborated with Southern California Edison and a third-party polling company to administer the survey to SCE's customers. To qualify, participants had to be at least 18 years old and had to be planning to buy or lease a new vehicle in the next five years. The survey focused on issues critical to the electric power industry: consumer charging preferences; accessibility of at-home charging; at-home charging plan preferences; the consumer's interest in acquiring an electric vehicle; and the influence of gasoline prices, vehicle price, and the consumer's friends and family.

Of 869 respondents, 292 owned a hybrid and 587 owned a conventional gasoline vehicle. Not surprisingly, interest in plug-in hybrid electric vehicles was highest among people who owned a hybrid. Some 20% of hybrid owners said they "definitely" plan to purchase or lease an electric car, compared with only 8% of non-hybrid owners.

Many survey questions dealt with charging, a topic customers identified as important in the 2001 survey. For example, do customers expect that there will be public charging? Where would they be most likely to charge their vehicles? Would they pay a premium for faster charging? Notably, nearly all respondents said they would prefer to charge their electric cars at home. "With a gasoline car, you go to the gas station once a week. With an electric car, you plug in when it's convenient," Duvall said. "That's an incredible benefit to owning an electric vehicle."

Researchers also asked participants when they would charge, if offered three options: an "anytime" plan that would allow them to charge day or night, a "night-time discount" plan that would give participants a discount for charging during off-peak hours, and a "night-time only" plan that would save participants even more money by letting them charge only during off-peak hours for a yearly flat fee. In California, participants preferred the "night-time discount" plan over the other two. Half of all non-hybrid owners and nearly 60% of all hybrid owners said they would choose this option. The "anytime" plan was least

The GM 2011 Chevrolet Volt is a plug-in hybrid. It has an unlimited driving range with its gasoline engine and an EPA-rated range of 35 miles on its battery. It will recharge from "empty" in about 8–10 hours using a 120-volt portable charger or in 3–4 hours from a dedicated 240-volt charger. Photo courtesy of Chevrolet.

The 2011 Nissan Leaf is a 100% battery electric vehicle with an EPA-rated range of 73 miles. It can use a portable 120-volt charger, but most drivers will likely opt for a dedicated wall-mounted 240-volt charger that can completely recharge the battery from "empty" in less than 8 hours. Photo courtesy of Nissan.

Ford plans to release the battery electric version of the Ford Focus in late 2011. The Focus Electric is powered by a lithium ion battery that can recharge from either 120 or 240 volts. Using the wall-mounted 240-volt charger can completely recharge the battery in as little as 3–4 hours. Photo courtesy of Ford.

desirable. The survey also presented an optional discount of $10 a month if customers would allow the utility to interrupt their charging occasionally. More than half of non-hybrid owners and 70% of hybrid owners were extremely or very likely to choose this option.

Regional Differences

What holds true for California customers may not hold true in other regions. "We looked at their (SCE's) results and said, we don't think that's our typical customer," said Bryan Coley, a research engineer with Southern Company. In 2010, EPRI researchers helped Southern Company in Atlanta implement its own survey of 500 customers. Atlanta is a city with long commute times and notoriously bad traffic, where residents might be inclined to purchase electric vehicles to cut their gasoline bills. "This was a great opportunity to benefit from a market research study already started by EPRI," Coley said. EPRI also launched a 1,000-person survey in collaboration with the Tennessee Valley Authority (TVA), which provides electricity to Tennessee and parts of Kentucky, Alabama, Georgia, Mississippi, North Carolina, and Virginia.

Responses to these surveys are strikingly similar, but differ substantially from California responses in two key areas. First, the percentage of Californians who said they would buy an electric car in the next five years was much higher. "That's not unexpected," Neenan said. "California consumers are more inclined to be 'early adopters'." Second, California respondents would be more willing to charge at night if the price of electricity were cheaper. That's important because drivers who come home from work and plug in their cars could be charging during peak demand and increasing stress on the electricity grid.

"Charging behavior is kind of the wild card in all of this," said James Ellis, senior manager of transportation and infrastructure at TVA. So utilities would like to offer customers an incentive for agreeing to charge when loads are lowest. The survey suggests that might work in California, where 66% said they would charge only at night or late at night, but that strategy might be more difficult to implement in the Southeast. When the survey offered Southern Company's and TVA's customers the same discounts, two-thirds of the respondents said they wanted to be able to charge at any time. This may reflect cultural differences or the Southeast's relatively cheaper electricity. "It really just shows that low cost energy economics is more of a driver here than the environmental benefits," Ellis said.

While responses differed among surveys, most differences were subtle. "One of the things we're finding is how alike people are," Neenan said. "That may mean we can administer surveys over regions rather than just in utility service territories." Participants from all three surveys said that faster charging would influence their decision to buy an electric car, but few participants indicated that they were willing to pay extra for faster charging options. Similarly, few participants were willing to pay a premium to purchase the car itself. In all three regions, respondents who said they would be likely to buy an electric car tended to be young, male, educated hybrid owners.

One section of the survey explored customers' expectations of their utilities. Responses indicate that consumers think that electric utilities will play an important role in the transition to electric vehicles. Between 50% and 70% expect the utility to offer home charging installation services and provide car readiness audits to tell them what upgrades they need to prepare their homes for an electric car. Many customers think that utilities should provide public charging stations. "Under the traditional model, a utility delivers power no further than the electric meter," Ellis said. But the survey results suggest that some consumers may like to see power providers

The plug-in hybrid version of the Toyota Prius, the top-selling hybrid in the U.S., is due to be released in 2012. It will use primarily battery power at low speeds and rely on its hybrid system and efficient gasoline engine at higher speeds. It should recharge from a 120-volt outlet in 3 hours. Photo courtesy of Toyota.

The Ford C-Max Energi is a plug-in hybrid electric vehicle that will be available in 2012. It relies on its battery at lower speeds and for stop-and-go driving. At higher speeds, the battery and gasoline engine work together to power the vehicle. Photo courtesy of Ford.

The Mitsubishi "i" is a battery electric vehicle already commercially available in Japan. Mitsubishi plans to begin selling the "i" in North America in late 2011. Photo courtesy of Mitsubishi.

think beyond that model. "It gives us more insight into what tools TVA can help our power distributors build in order to better meet consumers' needs," Ellis said.

Utilities may not be able to provide the services that customers expect for the prices they want to pay. Coley was surprised at how little customers offered to pay for conveniences such as 240-volt charging stations and faster charging. Purchasing and installing a 240-volt charging station, for example, can cost as much as $2,000, but more than 90% of customers said they wouldn't pay even $1,000. "Consumers always want the best value at the best price," Coley said. But the survey results make Coley suspect that customers need more education. Ellis agrees and added that consumers may not be taking into account the benefits of fuel switching. "The upfront costs of hardware and plug-in vehicles are more expensive right now," he said, "but there may be future financing models that can help make buying an electric car and supporting charging infrastructure more like buying a conventional vehicle."

"These surveys help utilities understand what their customers expect from them, but they also help EPRI understand what our research agenda needs to look like to be able to meet some of these requests," Duvall said. For example, given that people who have relatively cheap electricity seem to want the convenience of charging at any time, EPRI researchers might explore other incentives that could entice customers to charge their cars during off-peak hours; EPRI could then develop the technologies needed to deploy those incentives.

The Road Ahead

EPRI researchers plan more surveys, some of which may cover an entire state and allow several utilities to share the data. Once EPRI has data from several regions, it plans to create a national database of the survey responses. "The more data we have, the more we can learn," said Duvall. Coley would like to see the survey repeated in a few years. "At that point, our customers will have had some hands-on experience with the vehicles," he said.

Neenan calls the survey a first step. "This is an early market, so not everyone who wants an electric vehicle can get their hands on one," he said. "But as more automakers enter the market and the volume ramps up, we'll quickly get to a point where more people will think about buying electric vehicles. Because the current survey doesn't look at decision tradeoffs, the data can't be used to calculate a true adoption curve." Neenan and his colleagues hope to start working on a new survey in 2012 specifically designed to address those decision factors.

"Through this more probing research," he said, "researchers can look more closely at the decision to purchase an electric car and the impacts of the car's price, gasoline costs, and other factors." And knowing how many consumers will buy electric cars is the first step in preparing the electricity grid for this new fleet. "The industry is trying to anticipate how electric vehicles will change the demand for electricity," Neenan said, "so we don't get caught unprepared."

With better information, both Sam the car buyer and his utility power supplier may expect to arrive at the same plug at the same time for a successful "refueling."

This article was written by Cassandra Willyard. Background information was provided by Bernard Neenan, bneenan@epri.com, 865.218.8133.

Bernard Neenan is a technical executive in EPRI's Power Delivery and Utilization Sector. His research focuses on how electricity consumers respond to prices and information and on quantifying the benefits of disruptive technologies such as hyper-efficient energy devices, smart grid technologies, and electric vehicles. Neenan holds a B.S. and a Ph.D. in agricultural economics from Cornell University and an M.S. in food and resource economics from the University of Florida.

DATELINE EPRI

News and events update

OPEN HOUSE HIGHLIGHTS INNOVATIVE MERCURY CONTROL TECHNOLOGY

HENNEPIN, Ill. — EPRI and Dynegy Midwest Generation LLC co-hosted an open house at Dynegy's Hennepin Power Station in October, where visitors witnessed the operation of EPRI's Sorbent Activation Process unit, with the opportunity to assess its suitability for their power plants. The technology, which creates activated carbon from on-site coal supplies, is considered a promising, low-cost option for retrofitting coal-fired plants to comply with anticipated mercury emission limits.

FRANCE AND CALIFORNIA FOCUS ON ENERGY-EFFICIENCY OPTIONS

SAN FRANCISCO — The first California-France Forum on Energy-Efficiency Technologies was held in October, with EPRI experts leading panel discussions on various topics, including on-site renewable energy, industrial energy storage, industrial demand response, and energy-efficiency technologies.

WILMSHURST BRIEFS THE NRC ON FUKUSHIMA

ROCKVILLE, Md. — EPRI vice president Neil Wilmshurst appeared before the U.S. Nuclear Regulatory Commission on October 11 to discuss EPRI's perspective on the NRC's Near-Term Task Force Report concerning the Fukushima Daiichi accident. Wilmshurst addressed several efforts in which EPRI is providing technical leadership or support, including potential updates to the technical basis for severe accident management guidelines, evaluation of external hazards such as seismic and flooding, and modeling of radiological releases.

WORKSHOP EXAMINES CUSTOMER VIEWS ON ELECTRICITY

SAN ANTONIO, Tex. — Understanding How Customers Value and Use Electricity, a workshop co-hosted by EPRI and CPS Energy in October, investigated how to create the right mix of program offerings to achieve utility goals and appeal to a wide range of customers. Approaches include using insights from the behavioral sciences and incorporating information about customer differences. Perspectives from this workshop will inform an upcoming white paper that reviews the state of the empirical research on the topic.

EPRI WORKSHOP FOCUSES ON GRID TRANSFORMATION

CHICAGO — EPRI hosted 48 industry representatives from 25 companies at a November workshop at Argonne National Laboratory to detail the features and benefits of power grid transformation. Sessions focused on four core research areas: geospatial three-phase power system model requirements, seamless power system analytics requirements, integrated energy management systems coupled with analytics and grid measurement, and setting-less protection methods.

PLUG-IN 2011 DRAWS AN ENERGIZED CROWD

RALEIGH, N.C. — Organized by EPRI with support from Progress Energy and Duke Energy, the four-day Plug-In Conference and Exposition in July was attended by more than 600 utility, business, government, and university representatives; 50 exhibiting companies; and approximately 1,300 consumers. The annual conference shares best practices and highlights the collaboration needed to advance transportation electrification.

EPRI HEALTH SCIENTIST RECEIVES BOOK AWARD

LONDON — Gabor Mezei, program manager for EPRI's research on electric and magnetic fields (EMF) and radio-frequency (RF) emissions, received a 2011 British Medical Association Book Award. Dr. Mezei contributed two chapters on extremely low frequency and RF/EMF exposures in *Hunter's Diseases of Occupations*, 10th edition, earning first prize in the medicine category. The textbook is widely used as a reference by occupational physicians across the world and is considered an authoritative source of information on diseases related to work.

EPRI AND CRIEPI TO COLLABORATE ON KEY NUCLEAR ISSUES

TOKYO — In August, EPRI announced a three-year agreement with Japan's Central Research Institute of Electric Power Industry (CRIEPI) to jointly research issues related to nuclear power plant materials science, plant component performance, and radiation safety. The collaborative work will facilitate sharing research results, experimental data, and scientific information that will expand the knowledge of critical plant infrastructure and procedures. Results are expected to provide the technical foundation to enhance the safe and efficient operation of nuclear plants worldwide.

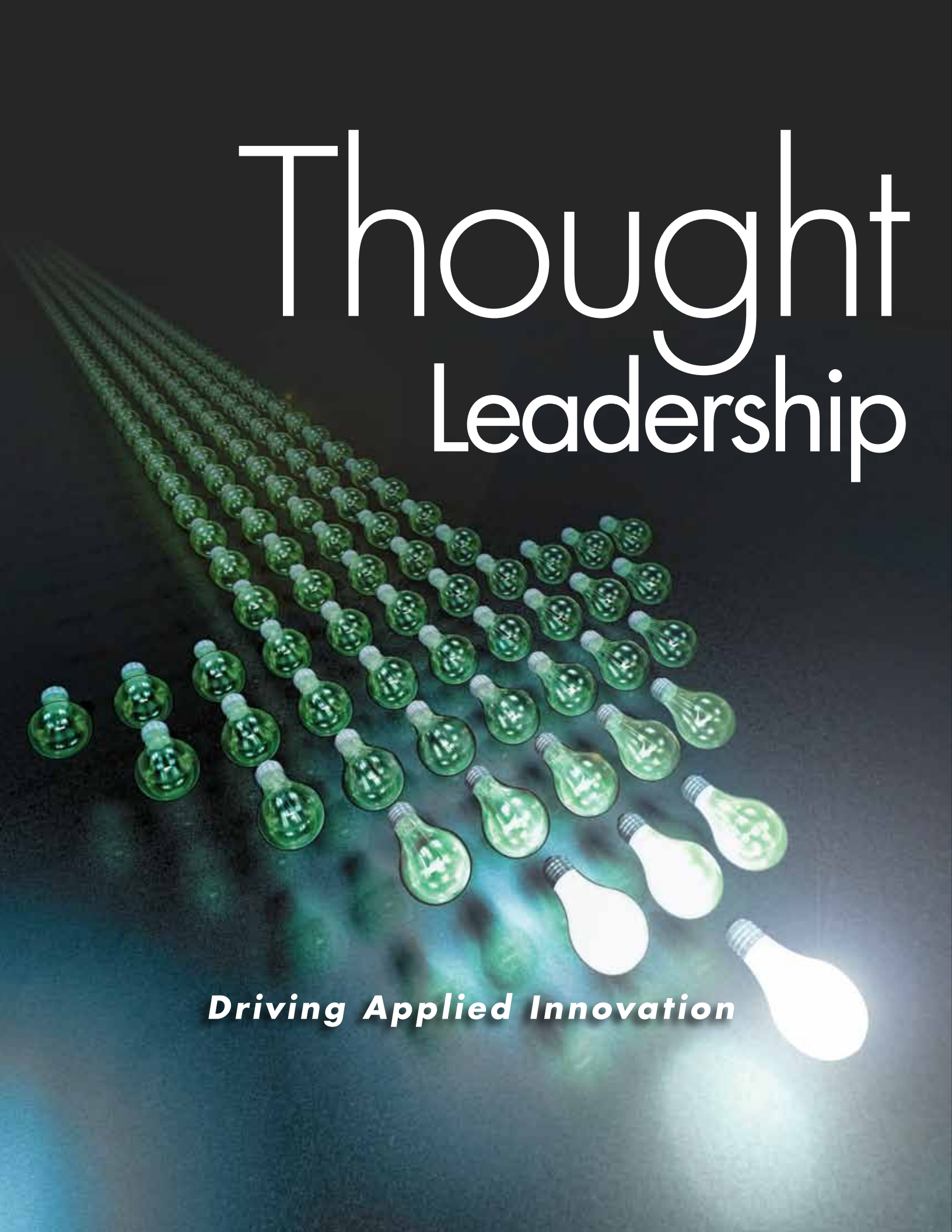
EPRI SEEKS R&D ALLIANCES WITH CHINA, SOUTH KOREA

SHENZHEN, CHINA, and SEOUL, SOUTH KOREA — EPRI president Mike Howard and vice president Neil Wilmshurst visited China and South Korea in October to discuss EPRI's research and development activities. In China, they attended the World Association of Nuclear Operators Biennial General Meeting and met with representatives from several Chinese utilities to explore the possibility of their joining EPRI. In South Korea, they met with senior executives from Korea Hydro & Nuclear Power Company to discuss KHNP's ongoing membership and further opportunities for greater engagement across EPRI.

REDUCING AGRICULTURAL GREENHOUSE GAS EMISSIONS

WASHINGTON, D.C. — EPRI senior program manager Adam Diamant hosted a workshop in November focused on the potential to reduce greenhouse gas (GHG) emissions by improving nitrogen fertilizer management in U.S. agricultural crop production. The practice of "nutrient management" could help reduce nitrous oxide emissions, a significant source of agricultural GHG emissions. This was the 11th in a series of workshops held from 2008 through 2011 as part of EPRI's Greenhouse Gas Offsets Policy Dialogue.

Thought Leadership



Driving Applied Innovation

THE STORY IN BRIEF

Broad collaboration and a structured innovation process are the keys to turning promising concepts into strategic real-world solutions. EPRI uses a nine-stage process to keep the pipeline full and guide ideas from exploratory research, through demonstration, to commercial application.

Scientists and technologists in universities, national laboratories, government agencies, and industry generate a continuing stream of ideas and insights. Their thought leadership is essential in creating solutions to address the electricity sector's strategic issues. Focusing this creative energy presents tremendous opportunities, but harnessing thought leadership to deliver and apply innovations requires a structured process.

Energy researchers' and developers' bright minds are often driven more by curiosity than exigency. Similarly, early-stage work in emerging disciplines may lack direction or urgency, even in entrepreneurial endeavors. To excel in applied innovation, researchers and developers must be able to:

- Understand and anticipate industry needs.
- Interpret the practical impact of new science and technology.
- Account for social, economic, and political factors shaping real-world application.
- Map and implement a research and development plan.
- Bring together the technical and financial resources to accelerate commercialization of priority innovations.

"Thought leaders generate innovative ideas, but that's not enough," said Arshad Mansoor, senior vice president of EPRI's R&D group. "What must follow is to move early-stage ideas into practice with a structured innovation process. EPRI does this with more than 500 EPRI technical staff, about 1,400 industry advisors, the worldwide science and technology community, and a broad array of stakeholders from more than 40 countries."

Focus the Thinking

A key in using thought leadership to drive applied innovation is to focus the thinking. In 2007, EPRI's Prism model first assessed the feasibility of achieving large-scale reductions in carbon emissions across the U.S. electricity sector and quantified the potential contributions of major technology options. It demonstrated that no "silver bullet" exists, that a full portfolio of advanced technologies will be required, and that substantial and sustained public-private R&D investment in key areas could lower the cost of meeting demand growth and reducing emissions by as much as $1 trillion. These findings helped a broad group of stakeholders arrive at a common basis for discussing and understanding the critical importance of technological progress in achieving climate policy goals.

Energy efficiency requires similarly creative approaches. A new study quantifies the huge potential for reducing energy use at generating plants and losses in transmission and distribution systems. "Just a 10% decrease in utilities' parasitic loads and delivery losses would produce energy savings equivalent to unplugging almost 4 million homes, which would have a far greater impact than ratepayer-funded efficiency programs," explained Clark Gellings, EPRI fellow. "This study highlights the importance of an end-to-end approach for improving efficiency, and it directs us to immediate opportunities for the electricity sector and promising avenues for innovation."

Add Structure, Send Scouts

EPRI applies a nine-stage process to manage its collaborative R&D portfolio and guide ideas from exploratory research, through validation and demonstration, to commercial application. Using nine technology readiness levels, the process identifies the advances required—or the knowledge and capability gaps that need to be filled—at any given readiness level to achieve the next level. Adapted from a system developed by NASA, the process helps EPRI maintain a full pipeline of promising ideas or breakthroughs and guide fast-track innovations toward commercial application.

This structured, quantitative approach is

particularly critical to guide innovation scouting during the early stages, when concepts are beginning to take shape. In the United States alone, tens of billions of dollars are invested annually in exploratory, high-risk R&D. Of the small fraction of concepts that prove technically feasible, a substantial percentage never escape "the valley of death" (technology readiness levels 4 and 5). Often, this is because requirements for real-world application are not well understood or because anticipated end users are not adequately engaged in the R&D.

For the electric power sector, it is essential to monitor early-stage R&D to capture innovation in strategically important areas such as energy storage, nondestructive evaluation, and carbon capture and in rapidly emerging disciplines such as nanotechnology, cyber security, and biotechnology. EPRI deploys what it calls "innovation scouts" across diverse areas of research. They identify a promising concept, conduct an independent evaluation, and then build collaborations to advance from one stage to the next, always with an eye toward technology readiness levels 6 to 8—real-world demonstration and early commercial deployment.

"Structured innovation is a way of harnessing creativity and the power of collaboration to increase the probability of successful R&D investment," said David Gandy, manager of EPRI's Technology Innovation Program. "What we need at the table is a clear understanding of the industry's needs, as well as collaborative participation of utilities and other stakeholders to nurture innovations and accelerate progress on potential breakthroughs."

Thought Leadership Thrives in a Big Tent

Electricity industry stakeholders include utilities and other energy providers, plus a much broader group—manufacturers, start-ups, academia, suppliers, government agencies and officials, environmental and labor organizations, consumers of all types, and the public. Decisions by legislative bodies, regulatory agencies, public utility commissions, and other authorities can have far-reaching impacts on the diffusion of advanced technologies. So too can market developments and the many factors that shape public perception and consumer behavior.

"Advancing technology alone is not enough to guarantee capital investment and commercial success," said Mansoor. "Some high-potential innovations at a high technology readiness level will not be widely deployed because the enabling policy, regulatory, and market frameworks are not in place. Knowledge of influencing factors can be as important as the technology itself."

The Carnegie Mellon Electricity Industry Center (CEIC), formed in 2001 at Carnegie Mellon University with core funding from EPRI and the Alfred P. Sloan Foundation, represents a large group of interdisciplinary researchers concentrating on data-driven, technology-informed policy, regulation, and investment in the electricity sector. It engages university professors, Ph.D. candidates and other students, and the full range of industry stakeholders in collaborative problem solving based on strategic issues and real-world case studies.

For example, the CEIC is developing a legislative and regulatory framework to address subsurface property rights issues likely to pace the adoption of geologic carbon sequestration. In another project, the ancillary service and arbitrage values of compressed-air storage systems and plug-in vehicle batteries are being quantified under different market conditions to identify approaches for monetizing social benefits and expanding the use of bulk and distributed storage technologies. The center is applying behavioral economics to develop strategies for increasing consumer participation in demand-response programs and deployment of new meters and energy management technologies.

Carnegie Mellon's RenewElec project brings a whole-systems perspective to the challenge of expanding U.S. renewable generation by more than an order of magnitude from present levels without adverse impacts on affordability and reliability. Such expansion implies a massive transformation of the nation's electricity infrastructure, which is contingent on progress in power systems engineering and the use of diverse technological building blocks. The RenewElec project aims to create an enabling framework of public policy and regulation that can help avoid problems related to geographic and political boundaries.

"Innovations in knowledge and technology across all realms are needed for variable and intermittent generation to achieve much higher penetration levels," said Jay Apt, CEIC director. "We challenge students to look a few moves down the chessboard, well beyond today's business cycles and political calendars, while maintaining objectivity and accounting for the inevitable uncertainties."

With core support from EPRI, the Laboratory on International Law and Regulation (ILAR) at the University of California, San Diego, conducts pioneering social science research, addressing the ways international developments influence institutions and investments in the energy sector and other sectors. Sample topics include the messy realities of climate policy and carbon markets, complex interactions between air quality regulation and climate change, and alternatives to the traditional spending-driven model of innovation.

According to David Victor, ILAR director, "Many issues of paramount importance hinge on factors beyond the electricity industry's control. An improved understanding of decision-making processes and outcomes will help us do a better job of predicting what kinds of institutions might emerge and how they'll impact technology investment and adoption at all levels. This knowledge is particularly critical in times of fiscal austerity and political gridlock."

Building the Future

Over the coming decades, advanced generation technologies for nuclear, coal, gas, and renewable plants—along with

supporting technologies such as carbon capture and storage (CCS)—will be required to supply growing demand affordably, reliably, and sustainably. Worldwide, utilities will require hundreds of gigawatts of new generating capacity and gigatons of CCS capacity, even as they transform today's transmission and distribution systems into smart grids. Tomorrow's electricity infrastructure projects must be addressed by today's thought leadership.

Siting new infrastructure will be a huge challenge. To inform strategic planning at the national, regional, and state levels, EPRI is supporting development of site-screening capabilities at the Oak Ridge National Laboratory (ORNL). Sites are characterized by technology requirements, regulatory considerations, and factors such as water availability, renewable resource quality, land availability and topography, and geological suitability for underground carbon storage. ORNL's unique capabilities in this area are expected to provide policy makers, regulators, and agency decision makers with perspective on the true deployment potential of individual generation technologies, the competition among options, the potential for transmission expansion, and other key factors.

Local opposition to large-scale projects is almost a given, even for renewables with high levels of public support. For less known technologies such as CCS, public acceptance is expected to prove crucial. EPRI is sponsoring work by the University of Sheffield to assess experiences with CCS demonstration projects in the United States and Canada and to identify key social factors influencing public perception. The ability to improve understanding and acceptance at the local level will be essential for streamlining the permitting of commercial installations.

"Thought leadership goes beyond imagination and creativity," said Mike Howard, EPRI president and chief executive officer. "We need multiple building blocks—those that anticipate needs and opportunities, those that advance new technologies from concept to commercialization, and even those that help us build tomorrow's infrastructure. Each building block in turn depends on individuals and organizations bringing their perspectives, skills, and tools to the process. Innovation begins with thought leadership, and it is carried forward with effective collaboration, scientific discipline, and a clear idea of how the innovations can help solve problems and address society's needs in the real world."

This article was written by Chris Powicki. Background information was provided by David Gandy, davgandy@epri.com, 704.595.2695.

Tapping Into Broad Expertise

The big-picture perspective and line-of-sight approach afforded by thought leadership help sharpen the focus on applied innovation and maximize the value of the industry's strategic investments. EPRI is collaborating with universities, national laboratories, and other research institutes to identify new opportunities and address specific technical and economic challenges. Greater detail on this work is available in a recently published EPRI fact sheet (1024712).

Energy and Policy Analysis

- Electricity Industry Center (CEIC), Carnegie Mellon University
- Laboratory on International Law and Regulation (ILAR), University of California, San Diego
- Energy Technology Assessment Center (ETAC), EPRI
- RenewElec, Carnegie Mellon University

Industry Leadership

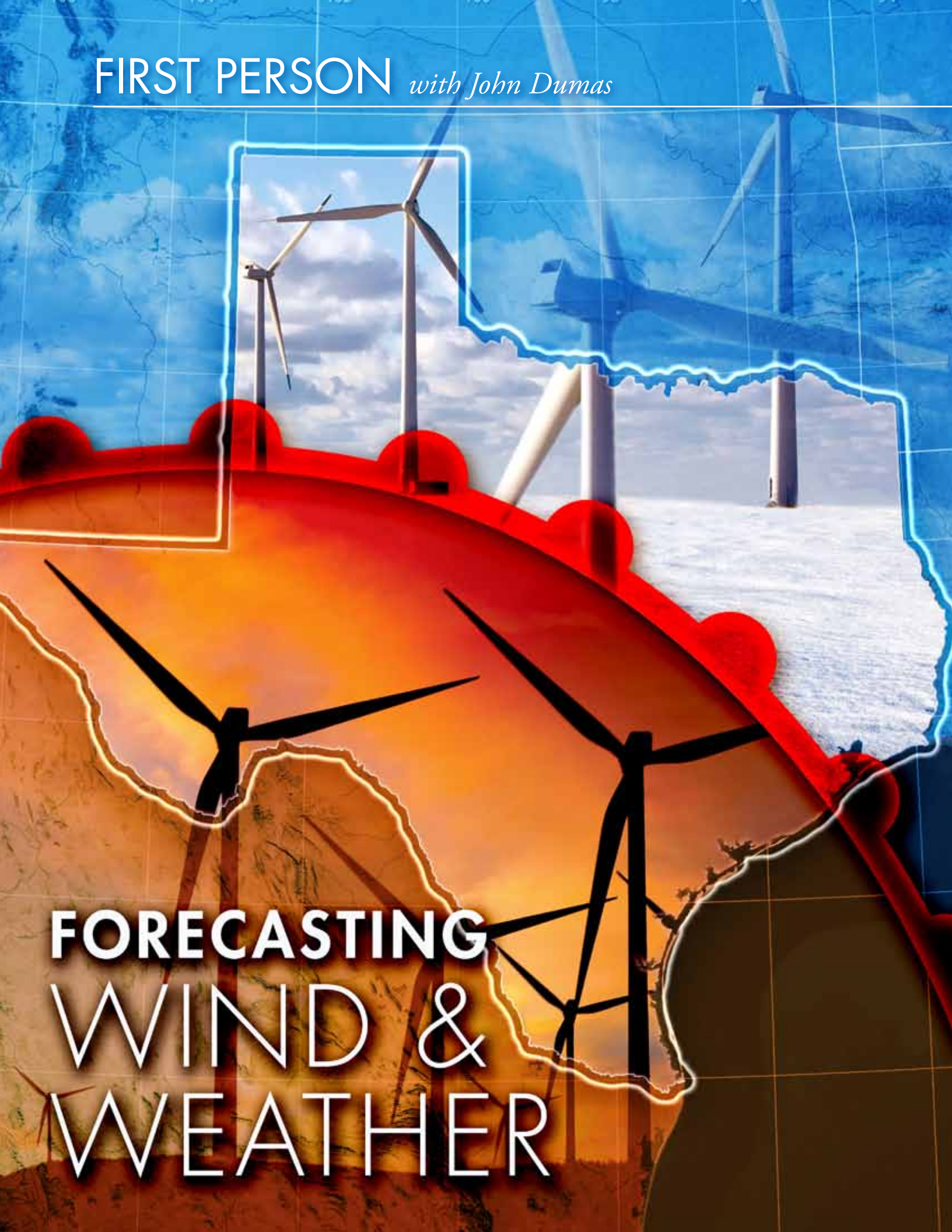
- Framework for Siting New Generation Plants, Oak Ridge National Laboratory
- Public Attitudes Toward Carbon Capture and Storage Technology, University of Sheffield
- Transmission Planning for Renewables Integration and Wholesale Competition, Program on Energy and Sustainable Development (PESD), Stanford University
- Revitalizing Electric Power Engineering Education, University of Minnesota
- National Electric Sector Cybersecurity Organization (NESCO) Resource, EPRI

University/Research Collaboration

- Power Systems Engineering Research Center (PSERC), Arizona State University
- Synchrophasor Network Laboratory for Power Systems Analysis and Wind Integration, University of Texas, Austin
- Electricity Research Center (ERC), University College, Dublin
- Power Industry Applications for Nano/Micro Science and Technology, Oregon Nanoscience and Microtechnologies Institute
- Design and Mentoring Projects, University of Tennessee; University of North Carolina, Charlotte; and Stanford University

David Gandy is the program manager in EPRI's Technology Innovation Program, where he is responsible for promoting innovative, exploratory, and strategic technologies throughout the Institute to accelerate the adoption of these technologies by the electricity industry. His duties include oversight of 18 long-range, strategic programs and management of a strategic program on Advanced Materials—Fossil and Nuclear. Gandy received his B.S. degree in materials science and engineering from North Carolina State University.

FIRST PERSON *with John Dumas*



FORECASTING WIND & WEATHER

John Dumas is Director of Wholesale Market Operations for the Electric Reliability Council of Texas (ERCOT), where he is responsible for real-time and day-ahead market operations and the monthly and annual congestion revenue rights auctions. He sat down with *EPRI Journal* to offer perspectives on the rambunctious Texas weather of 2011, the performance of the state's large and growing wind generation, and the state of the forecasting art.

EJ: Texas weather stayed in the headlines in 2011, starting with the winter storm before the Super Bowl and extending through the terrible summer heat. How did this story play out with respect to the state's large renewable energy base—particularly the wind resources?

Dumas: When we got into the week of August 1, there were about six days of what we call Emergency Energy Alert conditions. The loads were very, very high, and we used almost all of our reserves in supplying the load. We did not have to shed firm loads on any of those days. Any megawatt of load response that we got helped a lot, and any megawatt of wind generation that we got helped a lot. For three days in a row starting August 1, we set new peaks, and the peak on August 3 was 68,379 megawatts. On August 1, the wind accounted for about 4% of the generation on average and about 1.9% during the peak hour. On August 2, 5% for the day, 2.3% on peak. August 3, it was 4.7% for the day and 2.9% on the peak.

EJ: Watt for watt, was that 2% to 4% trickier to manage than gas turbines and so forth?

Dumas: The fundamental difference is that you have to think of wind more as "negative load." Just like load, you have to try to forecast it, and just like load, you have to account for the error in your forecast. With a generator, I know what your lead time is, and I know when I need to tell you to be on-line and available. I know what your high sustainable limit is, so I know what your output capability is and where I can tell you to go.

> **"The ability to forecast wind accurately increases your ability to manage the variation in wind; the more predictable wind is, the better you're going to be able to plan your other generation around that."** *~ John Dumas*

With a wind generation unit, you don't really think of it so much as a generator but as negative load; it's going to reduce my demand, and I'm going to have to cover with other generation by some amount. I have to be able to forecast how much that is and be able to account for the variability in the forecast.

EJ: How does that affect forecasting?

Dumas: We have models that forecast load, and we come up with our best load forecast. Historically, we know what the error is and what the volatility around that forecast usually is. The way we manage that is we submit ancillary services or reserves to put us in a position to manage any degree of error we had in our forecast. Wind is the same thing. You can net load and wind together and have a net load and develop some statistics around the net load forecast error. Your worst wind error doesn't necessarily happen at the same time as your worst load forecast error. It's really that combined load effect on the system you have to manage.

EJ: Does it introduce what feels like an element of randomness?

Dumas: I would call it variability. It definitely introduces a new variable that you have to manage. Wind forecast error is another component of the risk you have to manage, and you have to be able to account for that in your ancillary services or the reserves that you carry.

EJ: What's particularly challenging with regard to wind forecasting?

Dumas: What's tricky about a wind forecast and why it has more volatility than load is you're taking your wind speed and multiplying it by a power curve. The power curve is not linear, and at some point, small variations in wind speed can equate to significant variations in a wind turbine's power output. Our forecasters

are looking for a number of different weather events that can affect wind speed. Obviously, fronts moving through the area can affect wind speed, and in the summer when the daytime temperature heats up, it tends to reduce the wind speed. When the earth cools down at night, the wind speed tends to increase. Forecasters are also looking at wind feedback and adjusting their model as they move forward.

EJ: With the largest U.S. wind fleet right now connected to the ERCOT grid, how much wind power is ramping up or ramping down as wind condition changes?

Dumas: Well, you know you're going to have a morning load peak and an evening load peak. And then in the summer, you're going to have an evening load peak, and you know when it's going to happen. The difference in the magnitude of that peak is very much temperature- and weather-driven, and that's what you're trying to forecast for load. The peak hours for wind don't always happen at the same time on the same day. What we've seen with wind generation is very large ramps—up to 3,500 megawatts.

EJ: Does that mean in a particular hour or in a relatively short time, there could be 3,500 megawatts ramping up?

Dumas: We observed a 3,000-megawatt drop-off in a 60-minute period in the morning on May 5 this year. Then, on the other side, we've seen the wind pick up almost 3,000 megawatts in less than 60 minutes. We saw that in the morning on September 22 this year.

EJ: That sounds like quite a challenge for system operators.

Dumas: It's particularly challenging when it's on the way down. When you see it start down, what you have to do is look at the forecast, make some estimate—is it going to go from 6,000 megawatts to zero, or is it going to go from 6,000 megawatts down to 4,000? And do I have enough other generation on my system available to offset that drop? Those are the challenges a system operator faces.

> **"We have a nodal market system that looks at the current demand and determines the most economical way to serve that demand. In between those 5-minute dispatches, you have regulation service, which does the second-to-second smoothing."** *~ John Dumas*

EJ: How does the presence of a large wind fleet with the potential for these large ramps either up or down affect the reserves that you have on hand and how you bring them onto the system?

Dumas: We use the forecast to determine how much generation we need to commit to serve load, given the wind generation forecast. We also buy what we call supplemental ancillary services—gas turbines that can be started in 30 minutes or less—to manage the change in wind generation. What we've done is incorporated that forecast uncertainty into our process for determining how many gas turbines we need or how much reserve we need that has to be able to ramp up in 30 minutes or less. We combine that and our simulation services and the units that are on-line with our dispatch and our new nodal system. This gives us the ability to redispatch the system every 5 minutes. Prior to that, we were having to make tight decisions every 30 minutes.

EJ: Are your operators slicing the day into 5-minute increments?

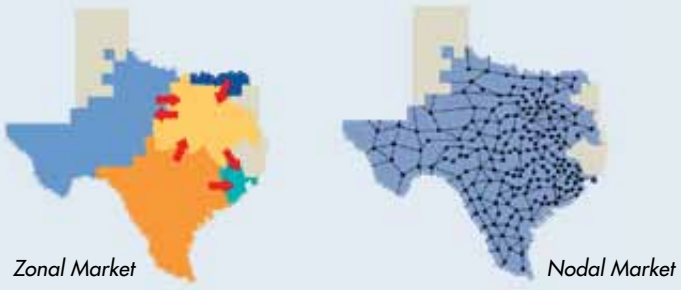
Dumas: They're watching how things unfold in real time. We have a nodal market system that looks at the current demand and determines the most economical way to serve that demand. In between those 5-minute dispatches, you have regulation service, which does the second-to-second smoothing. If wind is ramping up, then it's going to reduce the amount of gas generation that's needed to serve the load. If wind is ramping down, then you've got to increase output so you maintain that power balance. That's done by our nodal market system and our energy management system.

EJ: Last winter, national news coverage focused on the winter storm in Texas, with ice sliding off the roof of the new Cowboys arena and the damage to the power system. How did the weather and your wind resources play out during that pre–Super Bowl cold snap?

Dumas: That weather event was about instrumentation freezing up. We had over 100 generators that tripped off and a very high load because of the temperatures. Wind output was pretty good for the day; I don't think wind was a factor. In that event, the story was all about the extreme weather conditions, the instrumentation that froze up, and the units that tripped.

EJ: Given what you've seen, as more wind resources have come online, have you formed an opinion about where the next waves of innovation need to come from? Where should the industry, meteorologists, and researchers focus our attention?

Moving to Nodal Markets



Zonal Market *Nodal Market*

In 2010 ERCOT replaced its four "congestion management zones" with a matrix of more than 8,000 "activity nodes"—individual points where energy is added to or taken out of the grid, including generators, transmission lines, electrical buses, breakers, switches, and so forth.

The nodal system offers a number of advantages. Previously, congestion was managed between the four zones through pricing and dispatch activity tied to portfolios (specific groupings) of electrical equipment in each zone. Working across the state, the nodal system allows individual units to be brought on line rather than entire portfolios, addressing demand or congestion problems more efficiently, with the lowest-cost resources.

Prices are assigned to the individual nodes, making wholesale pricing more transparent and detailed. More accurate price signals indicate where additional generation and transmission is most needed—and where it is not needed—to efficiently manage congestion and maintain reliability. Independent analyses indicate that the improved pricing and scheduling of energy services can be expected to lower overall costs substantially in the long term, with consumer savings estimated at $5.6 billion over the first ten years.

The nodal market design holds particular promise for the more than 9,400 megawatts of wind generation capacity interconnected and operating in the ERCOT system. Wind generators are required to provide more detailed asset, telemetry, and modeling data for each machine, allowing the node to participate more effectively in wind generation forecasting. More robust generation data, along with revamped forecasting rules and requirements, are expected to improve the quality and timeliness of forecasts and increase confidence in their operational use.

Under the nodal system, there is a wider tolerance for deviation above and below base point—that is, generating more or less electricity than the scheduled output. The acceptable range above adjusted aggregate base point is 5% for conventional resources and 10% for intermittent resources such as wind. Such changes will substantially improve ERCOT's ability to integrate intermittent resources efficiently and reliably into ERCOT's overall system.

Dumas: Wind integration, in general, is the first hurdle. We have got the CREZ (Competitive Renewable Energy Zones) project that's going to build more transmission from west Texas into our load areas, which is going to increase our ability to transfer more wind output. And the ability to forecast wind accurately increases your ability to manage the variation in wind; the more predictable wind is, the better you're going to be able to plan your other generation around that.

EJ: Will that be helped by more powerful computers? Or is it more dependent on spreading your wind resources across a wide area and averaging things out?

Dumas: I think that's a good point. Your forecast is highly dependent on how accurate your weather models are. How volatile your wind output is—that's dependent on the area your wind is in and the diversity. In Germany, forecasts are pretty good because their wind tends to be spread out over the country. It's pretty diverse, and their wind volatility is much less than what we experience.

In Alberta, Canada, in areas where there are mountains, wind volatility is pretty high, which makes forecasting very difficult. It's all a matter of the weather patterns and the diversity. Another factor is the number of meteorological towers you have to measure and monitor the weather conditions.

EJ: Overall, you seem comfortable with the job you've got to do and your performance to date.

Dumas: You know, necessity is the mother of invention. Wind is here, and I think we've done a pretty good job of managing it and moving forward with the best ways to manage it. We developed a ramp rate forecaster that we put in place last year, which tries to predict the probability of a large ramp and the magnitude of that ramp over the next 6 hours. As far as I know, we're the first ones to do that. So we look for better ways to predict what the wind's going to do and improve our ability to manage and respond to that variability. I think we've shown that you can manage pretty large amounts of wind capacity and manage the variability of wind output through the use of your systems that dispatch, the use of ancillary services, and the use of your forecasting tools.

Biotechnology for Removing Boron from Wastewater

Boron, a naturally occurring component of coal, is a particularly problematic constituent. In sufficiently high concentrations, the element can pose a human health risk, yet no cost-effective technology exists to remove it from power plant effluents. With new wastewater quality regulations expected soon from the Environmental Protection Agency, EPRI researchers are investigating two biotechnological approaches to boron removal that could be applied at many coal-fired generating stations: constructed wetlands and bioreactors.

Constructed Wetlands

Man-made wetlands mimic natural wetlands and can be an efficient way to filter wastewater and eliminate potentially harmful contaminants. Earlier EPRI research developed genetically altered plants to treat selenium and other trace metals from power plant effluents. Wetland plants that absorb and sequester boron could similarly provide a natural, cost-effective method for capturing and removing boron from wastewater. To be effective, the plants must be able to absorb large amounts of the toxic element without being poisoned; when the boron has been bioaccumulated to a significant concentration, the plant would then be harvested and disposed of in an appropriate waste management facility.

In 2010, EPRI researchers identified two boron-tolerant plant species native to Turkey—Puccinellia distans and Gypsophila arrostii—and lab-tested them for their ability to tolerate and sequester boron. Although both species exhibited unique abilities to hyperaccumulate boron, Puccinellia distans had an especially high tolerance, surviving water concentrations of 1500 mg of boron per liter. Actual coal plant effluent concentrations are not expected to exceed 120 mg per liter.

Physiological analysis of the two plant genotypes revealed that they exhibit significant differences in how they tolerate and sequester boron, and the EPRI team is working to identify and characterize the genes responsible for the plants' toleration, transport, and sequestration mechanisms. Researchers hope to use these genes to enhance the capabilities of other, native wetland plants to take up and sequester boron. The next steps will be to test the plants in laboratory-scale experiments and small field studies.

Bioreactors

While man-made wetlands show great promise for boron reduction, they are expected to be less effective in the cold winter months, when vegetation becomes dormant. A second approach, bioreactors that hold boron-consuming bacteria or algae, could provide another cost-effective way of treating wastewater. To search for boron-tolerant algae and bacteria, EPRI researchers collected soil samples from a site with natural deposits of boron.

Mature Puccinellia distans in a hydroponic greenhouse setting

The research team has isolated and characterized a strain of the bacterium Bacillus boronensis that appears to be extremely boron tolerant, surviving up to 7,567 mg of boron per liter on solid medium and 5,405 mg in liquid medium. The bacterium has pH optima of 8.0 at 30°C (86°F) and 7.0 at 40°C (104°F) and demonstrated its highest growth rate at 40°C (104°F). In addition to being boron tolerant, it is highly salt tolerant, able to survive up to 15% NaCl in solution—a valuable attribute for treating effluents with high salt concentrations.

Boron-tolerant organisms such as Bacillus boronensis could be used directly in a bioreactor for wastewater treatment, but their study may also yield information on novel molecular mechanisms of boron tolerance, which could then be used to genetically engineer bacteria even better suited to a bioreactor system. Moreover, boron-tolerance genes could be used to create transgenic plants with superior capacities for boron tolerance and accumulation. As with the constructed wetlands research, the next steps for a bioreactor approach are laboratory-scale tests and field studies.

EPRI's wetlands and bioreactor research have good individual potential for solving utilities' boron challenges, but their combination may provide the best overall approach. Wetland systems, which are less effective in cold weather, could be supplemented with bioreactors on the same site that are geared to take over during the winter. By combining the two approaches, electric power companies may be able to operate a cost-effective wastewater treatment system for boron removal that works efficiently year-round.

For more information, contact John Goodrich-Mahoney, jmahoney@epri.com, 202.293.7516.

Analytical Framework for Energy Efficiency and Carbon Reduction

Energy efficiency and carbon emissions reduction are key considerations for today's industry as it prepares for tighter regulations and a greener energy future. But incorporating these issues into a company's project planning can be difficult because their costs and benefits are hard to compare with other operational and capital investment concerns on an "apples to apples" basis.

To simplify and clarify the decision-making process, Ameren and EPRI developed an analytical framework to compare the costs and benefits of energy efficiency and carbon emissions reduction projects at Ameren's buildings and facilities across the entire spectrum of its operations. Ameren successfully applied this framework to identify, rationalize, and prioritize potential energy-efficiency projects in its 2011 Integrated Resource Plan filing, for which the Missouri Public Service Commission instructed utilities to evaluate energy-efficiency opportunities in their own operations. The framework is expected to be adaptable for wide use across the utility industry.

Developing the Framework

Evaluating and comparing projects across a company's internal operational boundaries can be a particular challenge. To promote comprehensiveness and synergy, Ameren brought together leaders from many of its functional areas—including corporate strategy, plant operations, transmission operations, distribution operations, facilities management, and customer energy efficiency—to discuss potential projects in their respective areas.

The research team established an accounting framework for quantifying the benefits and costs associated with the projects. For example, the framework established guidelines for how to attribute incremental costs to projects whose primary purpose was energy efficiency or carbon benefits versus projects primarily intended for other purposes. The process also established metrics that allowed projects to be compared with each other on the basis of levelized cost. Drawing on EPRI's extensive experience with other utilities, the team developed a repository of projects with efficiency and carbon impacts that included generic projects in addition to Ameren's existing project initiatives.

"As a team, we identified all the energy-efficiency projects we could imagine—from our distribution system to our power plants to our own buildings," stated Bill Davis, senior load research specialist in Ameren's corporate planning function. "Company employees ran the numbers and used institutional knowledge to determine which efficiency opportunities would be the most promising. This research project was a great catalyst

that helped us prioritize and gave us the framework to move forward. It allowed us to quantify what was important, challenge the status quo, and discover new things in the process."

In light of such benefits, Ameren has established the process as a "living framework" to evaluate and catalog future projects and has already extended it to assess the costs of using amorphous-core transformers to improve distribution system efficiency.

Industry Opportunities

By applying the framework, Ameren was able to prioritize high-impact, low-cost projects that it could effectively incorporate into its internal corporate planning and communicate in its external resource planning filings with regulators. In addition to the Missouri Public Service Commission, Ameren has shared the results with the Missouri Office of Public Counsel, the Missouri Department of Natural Resources, and several industry intervener groups.

Going forward, other utilities may emulate Ameren's example by adapting the methodology, which can easily be customized to their particular circumstances. Such a framework can help the industry take heuristics and guesswork out of the evaluation process, replacing them with a methodical, reasoned, fact-based approach for evaluating the potential magnitude and cost-effectiveness of capital improvement initiatives. In many cases, utilities may find that efficiency improvements to their own facilities or power delivery infrastructure can result in considerable benefits attainable at lower costs than traditional customer end-use programs—opportunities that can be difficult to see without a quantifiable framework approach. With the clarity and specificity such a framework provides, the industry can, in turn, inform and educate public stakeholders about the potential and value of an end-to-end energy-efficiency perspective.

For more information, contact Omar Siddiqui, osiddiqui@epri.com, 650.855.2328.

Sequestration Resins Accelerate Contaminant Removal from Nuclear Plant Coolants

During maintenance and refueling outages, current ion exchange resins used to treat light water reactor coolants may require several days to reduce the concentration of radioactive corrosion products to acceptable levels. This influences outage schedules and replacement power costs, while residual contamination in cooling water contributes to overall site radioactivity levels and occupational exposures. EPRI's Technology Innovation Program is developing novel sequestration resins engineered specifically for faster, higher-capacity uptake of soluble corrosion products. These resins can also be used during power operation with existing plant water treatment systems.

Capturing Corrosion Products

Elemental cobalt (Co-59) and nickel (Ni-58) are released into solution by corrosion of welds and base metals in primary water systems. They may be activated by radiation to form Co-60 and Co-58, the isotopes responsible for the majority of dose exposures in boiling water reactor (BWR) and pressurized water reactor (PWR) environments, respectively. Current ion exchange resins used in reactor water cleanup and other applications can remove 90%–99% of activated and unactivated corrosion products for a short period after entering service, but most of their absorptive capacity is quickly consumed.

EPRI-developed sequestration resins preferentially target activated and unactivated cobalt and nickel ions and lock these impurities within their chemical structures through geometric and electronic interactions at active binding sites. Laboratory proof-of-concept testing in 2009 on an experimental batch of sequestration resin in powder form demonstrated substantial increases in cobalt uptake as compared with traditional ion exchange materials.

In 2010, sequestration resin powders optimized for reactor water treatment were synthesized and evaluated on simulated coolants in the laboratory and then on primary coolant and spent fuel pool samples at Exelon's LaSalle County Generating Station. Enhanced Co-60 removal was observed, in terms of both rate and sequestration capacity for a given amount of resin. Similar results were observed during high-throughput testing on reactor water cleanup samples from LaSalle and during an initial evaluation of radioactive wastewater samples from NextEra Energy's Seabrook Station.

Further Lab and Field Work

Continuing laboratory research in 2011 focuses on understanding and optimizing resin synthesis, chemical structure, and removal efficacy through scaled mockup tests of a filter/demineralizer system. In conjunction with specialty chemical companies and potential resin vendors, researchers are developing large-scale synthesis methods for production of EPRI patent-pending powder- and bead-form sequestration resins. Parallel experimental studies address bed regeneration and waste disposal issues and feedwater filtration and radioactive waste treatment applications.

Experimental cobalt sequestration column used in resin testing

Initial in-plant testing is expected to begin in late 2011 at a BWR to evaluate the performance of the sequestration resins in comparison with conventional ion exchange resins in the plant's reactor water cleanup system. Follow-on demonstrations are planned for PWR coolant applications, as well as for radioactive waste treatment applications for both BWRs and PWRs. Reactor-grade sequestration resins are projected to be ready for commercial application at light water reactors within three years. These resins are expected to provide at least a threefold increase in removal rates for key transition-metal impurities, supporting dose reduction and accelerating access to the reactor refueling floor during outages. By reducing the wait time before entering containment from up to three days currently to one or two days, nuclear plants could save as much as $1 million to $2 million in replacement power costs alone. In addition, higher overall removal efficiencies will reduce occupational exposures and waste management costs. The use of these resins during full power operation will also support source term reduction of ionic species known to contribute to elevated dose rates in specific plant areas.

For more information, contact Susan Garcia, sgarcia@epri.com, 650.855.2239, or Paul Frattini, pfrattin@epri.com, 650.855.2027.

Biomass Leaching Pretreatment Improves Fuel Quality

Biomass, a renewable and almost CO_2-neutral option for power production, is one of the most attractive possibilities in the search for alternatives to fossil fuels. As has been demonstrated in pilot programs, forest residues and fast-growing tree species can be fired directly or in combination with conventional fuels or can be converted to a new form of biofuel through thermochemical processes such as gasification. But agricultural wastes may provide a cheaper and more widely available biomass feedstock for power production than forest resources. With agriculture dominating the landscape in most parts of the world, crop residues such as straws, olive residues, hulls, and pods are the most abundant biomass resource, especially in underdeveloped and environmentally sensitive areas.

In contrast to wood fuels, the lower-quality agro-residues contain relatively large amounts of reactive alkali metals—potassium, sodium, calcium, and magnesium—as well as chlorine, sulfur, and phosphorus. Unfortunately, the presence of large amounts of these inorganic constituents during combustion or gasification can leave deposits on walls and heat exchange surfaces and cause slagging, fouling, and corrosion/erosion damage to plant internals. The compositional disadvantages of agricultural biomass and waste materials will need to be overcome if they are to be widely used in electricity generation.

Bench-Scale Testing

EPRI is investigating the potential of pretreating the biomass feedstock through chemical leaching to remove its troublesome constituents. In an extensive set of bench-scale tests, researchers treated ten different biomass and waste materials, from switchgrass and wheat straw to olive residue, sugarcane trash, and rice hulls, to assess and optimize a variety of innovative leaching technologies. The test fuels were all selected for their high potential to be used as low-cost feedstock for energy production. The solvents ranged from tap and deionized water to organic and inorganic solvents of various acidities, including some special solvent formulations expected to impart beneficial properties to the pretreated materials, such as high reactivity and increased calorific value.

The researchers performed extensive laboratory analyses of the initial biomass and waste materials, the resulting leached materials, and the liquids from the leaching process to fully assess the effectiveness of the technology. Test results allowed the researchers to zero in on the best solvent mixtures for each material, as well as the most effective concentrations, treatment times, and temperatures. Solvent concentration was found to be the most important variable for outcome effectiveness, followed by leaching time and solution temperature. The leaching process was modeled in detail with the Aspen Plus chemical modeling tool, and the process economics were also evaluated.

Filtering olive residue leachate in the laboratory

The leaching technology was proven to work efficiently for all the test materials. In all feedstocks tested, the content of reactive alkali metals in the leached products was reduced by more than 90%, chlorine by more than 99%, and sulfur and phosphorus by 30%–80%. Ash melting points were increased by 400°C–800°C (752°F–1,472°F), depending on the solvents used and the specific biomass material treated.

Next Steps

With such positive bench-scale results, EPRI plans to participate in the construction of a 1-metric-ton/hour pilot-scale leaching plant in the coming year to test the parameters of the leaching process in a continuous mode and optimize the different process components; this fine tuning at pilot scale is expected to reduce the operational and capital costs that will be incurred for a large-scale demonstration leaching plant.

The pilot plant will produce 14–20 tons of clean biomass as well as 1–3 tons of clean biocoal (torrified briquettes) from a variety of biomass materials. The fuels produced will be submitted to combustion and gasification tests to validate the effectiveness of the leaching process in eliminating problems during direct firing, gasification, and other thermochemical processes. The pilot plant will also be used to train the operators of future commercial leaching plants, to quantify the actual performance of the different process components, and to guide the engineering and design of leaching plants at demonstration/commercial scale.

For more information, contact Luis Cerezo, lcerezo@epri.com, 704.595.2687.

Secure Remote Access to Transmission Line Fault Data

Data on relay activity, circuit breaker operation, and high-speed waveforms provide critical clues to the location and dynamics of transmission line faults. Known as non-operational data, this information is used by system control and maintenance crews to locate and correct faults before they put the system at risk and by protection engineers to understand how and why an event occurred in order to prevent a similar occurrence in the future.

Non-operational data are collected at the substation by intelligent electronic devices (IEDs) such as digital fault recorders, digital protective relays, and circuit breaker recorders. But gathering and analyzing the data has generally been a time-consuming and difficult process, with readings typically being sent from the substation to the control room through dial-up communication links or retrieved manually by maintenance crews sent to the site. In the former case, the data transfer process can be lengthy, and connections can be dropped, forcing the utility to start the retrieval process again. If information from several substations is not available to help analysts triangulate on the trouble spot, maintenance crews may need to spend hours visually patrolling the lines to pinpoint the exact location.

Working with FirstEnergy, EPRI has developed a methodology to provide secure remote access to substations via wide-area networks to capture fault information, bring it back to a central data warehouse, and interpret and present it in a standardized format for protection engineers, maintenance personnel, and operators.

Centralized Data Warehouses

As utilities move forward with initiatives to create smart grids, it becomes increasingly important to automatically import and integrate substation IED data into centralized data warehouses. Here, the raw data from a number of locations can be automatically integrated, converted to non-proprietary formats, and extracted in tailored form to aid in the decision making of different functional groups. For example, basic high-level information about the fault could be sent to the operations and maintenance groups for immediate action, while more detailed information could go to the protection engineer for full analysis.

The tailored format not only ensures that a group will get the specific information it needs, but it also weeds out unwanted data and detail that can cause information overload. This process is often referred to as an "information smart" approach. Because utilities use a wide range of vendor-specific and often proprietary systems to capture IED data, the ability to display information in the data warehouse in a standardized, tailored format is a key feature.

Inside the data warehouse, information is stored using IEEE industry standard–compliant naming conventions. Using the suite of software modules developed under EPRI's Multiple Uses of Substation Data project, the information can be readily integrated with key utility application systems, such as substation automation, supervisory control and data acquisition, energy management, geographic information collection, outage management, asset management, and lightning detection.

FirstEnergy's Smart Grid Testing Facility

The methodology was proved and demonstrated at FirstEnergy's Smart Grid Testing Facility. Data for the project were taken from two of FirstEnergy's operational substations and automatically imported into a centralized data repository. An initial substation data integration project led FirstEnergy to require that the data acquisition feature be accomplished in a more secure manner, in alignment with North American Electric Reliability Council (NERC) Critical Infrastructure Protection (CIP) requirements—requirements many utilities are struggling to meet. Because the testing lab is equipped with internal network connections, conducting the work there ensured a secure, controlled environment in which security probes and tests could be conducted without impacting the substations or stranding unsuccessful pilot solutions in the field.

The work, a compilation of efforts conducted over a three-year period, demonstrates that automated data integration and analysis is possible and can offer multiple benefits to utilities. The next step will be to expand the system beyond the lab and verify practical application with a larger set of substations.

For more information, contact Paul Myrda, pmyrda@epri.com, 708.479.5543.

EPRI Study Clarifies Thermal Discharge Risk

Power plants that use once-through cooling and recirculating systems must comply with state and federal regulations to ensure that the higher temperature of discharged cooling water does not affect the health and diversity of fish and other aquatic species. In most cases, appropriate exit temperature limits are easy to formulate and have been standardized. But in some cases, where the river's elevation and flow are atypical, the situation becomes more complicated. Tri-State Generation and Transmission Association, facing such a challenge at its Nucla Station in southwest Colorado, turned to EPRI for help.

Tri-State's 100-MW Nucla Station

Nucla: An Unusual Case

The Nucla Station is situated adjacent to the San Miguel River and uses its water for the plant's recirculating wet cooling towers. The plant is located approximately 3 miles upstream from the end of a 48.5-mile section of the river in which the elevation drops steeply from 8,700 feet to 5,700 feet. The river is fed primarily from snowmelt from the San Juan Mountains and also receives runoff from rainfall, although the area surrounding the Nucla Station is semi-arid. During the summer, the flow of the river decreases significantly because of agricultural withdrawals and dry summer conditions.

In an effort to clarify the effects of these unusual circumstances, a Tri-State team conducted temperature and aquatic life studies to gain a better understanding of the river's ecosystem, sharing the results with various state agencies at rulemaking hearings in 2001 and 2006. At the 2006 hearing, the state agencies agreed that the segment of the river near the Nucla Station was a transition zone for the river's natural temperature habitat. However, the agencies required Tri-State to conduct additional studies to determine whether the station's discharge was affecting the aquatic community and what the appropriate temperature habitat classification should be for that section of the river. Tri-State asked EPRI to conduct the study. According to Chantell Johnson, senior environmental planner at Tri-State, "We wanted to make sure that we addressed all of the issues, and EPRI had a wealth of knowledge that no one else could provide."

A Robust Study Design

The project team focused on field-sampling aquatic biological populations and river temperatures in 2008 and 2009, as well as reevaluating the data collected during Tri-State's 2005 aquatic life assessment. Several sites were sampled, including new sites that bracketed the mixing zone where the plant's thermal discharge entered the river. The study used conventional population counts and biomass measurements, but also incorporated condition factors, reproduction viability, and tributary evaluation. In addition, a new methodology using 13 different metrics was utilized to assess the populations of macroinvertebrates, such as insects and their larvae. Macroinvertebrates not only serve as food for larger aquatic species, but are themselves sensitive to water conditions, serving as ongoing biomonitors of the water environment's sustainability.

The study established that fish and macroinvertebrates were not affected by Nucla's thermal plume. As EPRI's Bob Goldstein explained, "This was a robust ecological assessment because we were not only studying effects on individual fish populations, but also determining the river segment's natural thermal habitat."

In 2010, Tri-State met with state agencies during a special hearing. Agreeing with the EPRI study results, the state agencies determined that there was no negative impact on the aquatic community from Nucla's thermal discharge and that the unique ecosystem surrounding the plant merited the adoption of site-specific standards. In addition, Colorado's State Water Quality Control Commission decided that the section of the river near the plant—both upstream and downstream—should be reclassified as warm-water habitat.

As a result of this study, a new methodology exists to assess thermal discharge effects on a variety of river types, including high-elevation, low-summer-flow rivers such as the San Miguel. In addition, Tri-State avoided the potential cost of installing a chiller to cool the plant's thermal discharge, which would have been required if a standard temperature classification had been imposed for the river.

For more information, contact Robert Goldstein, rogoldst@epri.com, 650.855.2154.

TECHNOLOGY AT WORK

Member applications of EPRI science and technology

Smart Grid Interoperability Testing

As smart grid technologies evolve, it becomes increasingly important that the interactions among utility systems and equipment, front and back office personnel, and customer equipment be streamlined to achieve the greatest possible levels of efficiency.

To better understand these interactions, EPRI recently partnered with American Electric Power (AEP) to develop 21 "use cases" describing interoperability requirements for smart grid applications such as advanced metering infrastructure, demand response, distributed grid management, electric transportation, and energy storage, among others. Achieving interoperability—efficient transfer of information among communicating devices and individuals—is often complicated because the equipment and systems involved use different and sometimes proprietary standards to communicate, and the individuals involved have different skill sets and responsibilities.

Use cases are process descriptions that define the information that needs to be transferred to bridge these gaps. The end product is a written document defining the various interactions between data streams (sensors, control commands, use and billing data), communications mechanisms (power lines, wireless, internet protocol), field devices (meters, power quality devices, operating software), and the various individuals and departments involved in operating them. The use case document clarifies how best to facilitate communications among these various human and equipment "actors" for a specific smart grid application or service.

Example: Developing a Pricing Signal

In one use case to facilitate a real-time pricing system, a pricing signal was developed, and interactions were identified to allow customers to receive and respond to the signal via a computer portal. Using this information, the customer could defer activities such as dishwashing when prices were high, set up an energy use profile to manage costs, or let the system make recommendations to achieve this goal. The following key information is included in this and other use cases:

- ***The goal***—for example, in a pricing application, rescheduling the use of home appliances to avoid operation during peak demand prices
- ***The narrative***—a short English text version of the interaction
- ***The actors***—anything in the system that communicates: a person, a device, a piece of software, an organization, or another entity
- ***The steps***—a numbered list of events identifying the actors, what the actors do, what information is being passed, and to whom or what the information is passed
- ***The contracts and preconditions that exist between the actors***—for example, agreements to limit demand on selected days in exchange for a lower tariff

AEP's gridSMART Demonstration Project

The 21 use cases were developed to define opportunities to expand AEP's gridSMART demonstration project. The project is one of the first of its kind to integrate advanced technologies in the distribution grid, utility back office, and consumer premises so that products, technologies, and services can be incorporated within a single, secure, two-way communication network between AEP and its customers. EPRI's IntelliGrid[SM] methodology was used to analyze AEP's business processes and record requirements to create the use cases. The IntelliGrid methodology defines requirements for technologies and communications, information, and control infrastructures to support integration. Use of the methodology substantially accelerated development of AEP's integration test plan, allowing it to describe required business functions and translate those for its diverse group of stakeholders more accurately than would have been possible using other analysis methods.

The use cases, developed over a period of six weeks, have been packaged in a 400-page document (1021464) and are also viewable at EPRI's use case repository, accessible at www.smartgrid.epri.com. Many groups involved in smart grid developments are searching for smart grid use cases that can be used to prepare requirements, standards, and test cases, and AEP has been proactive in sharing its use cases broadly throughout the industry. For example, the Multi-Speak® community will use the cases to develop service definitions for the domains the cases represent, and the Smart Grid Interoperability Panel will use them as input to National Institute of Standards and Technology (NIST) standards and development processes.

For more information, contact John Simmins, jsimmins@epri.com, 865.218.8110.

Exelon Uses Guided Wave Inspection to Assess Underground Piping

While pipe leaks and spills do not pose a threat to public health and safety, nuclear power plants implement comprehensive leak inspection and mitigation programs to ensure that soil and groundwater near the plant are protected. Many pipes in question can be examined directly, by means of ultrasonic scanning or other conventional nondestructive evaluation (NDE) techniques. But some plant piping extends through complicated mazes of operational equipment, through walls and barriers, under the ground, or beneath structures, making it difficult to access for inspection. In some cases, maintenance engineers may excavate an entire pipe section for integrity testing, but they risk damaging the pipe or other assets in the process.

Pulses and Echoes

Working with Exelon at its Oyster Creek Generating Station, EPRI demonstrated that guided wave inspection, an innovative approach used primarily in the aerospace, gas pipeline, and refinery industries, can be successfully adapted for power plant pipe corrosion detection.

The guided wave technique can be used to examine the integrity of long runs of piping—up to several hundred feet when the pipe is not in contact with soil—from a single probe location, requiring only small portions of the pipe to be exposed and instrumented. Transducers mounted around the pipe's circumference produce a low-frequency wave pulse that travels along its length; when the wave encounters corrosion in the pipe, it is reflected as an echo, which is detected and recorded. Analysis of the echo's amplitude and arrival time tells operators how far down the pipe the flaw is located. The echoes produced by welds and other pipe junctions carry their own identifiable wave signatures, which can be distinguished from corrosion echoes and ignored. Transducer systems specially designed to be mounted permanently underground can facilitate ongoing periodic examinations.

Application at Oyster Creek

Exelon personnel were concerned about the integrity of two pipes at Oyster Creek: a 12-inch-diameter (30.5 cm) condensate transfer line running through a series of three 16-inch (40.6 cm) carbon steel barriers, and a 6-inch (15.2 cm) fuel pool cooling line running through two 12-inch (30.5 cm) holes bored through concrete. The piping exits the turbine building, runs below ground, and penetrates another wall as it enters the reactor building. The pipe wall penetration had been sealed with grout, blocking access for investigation via conventional NDE techniques. Recognizing the inspection challenges, Exelon asked EPRI to help evaluate potential options for assessing the integrity of the piping system.

Guided wave sensors installed on piping mockup

To confirm that a guided wave inspection would be effective for Oyster Creek, EPRI built a full-scale mockup of the piping system to simulate field conditions, set up the hardware and test parameters for the guided wave inspection, and demonstrated that the technology could detect target flaws in the mockup. To increase accuracy and sensitivity, the researchers chose a phased-array configuration for the transducers, which allows energy to be focused in both circumferential and axial directions. The successful trials with the mockup enabled EPRI to transfer the technology and knowledge to Exelon's inspection vendor for field deployment, with EPRI providing oversight during the actual inspection of the two lines.

"The project went very well," said Exelon's Kevin Leonard, Buried Pipe and Raw Water Program owner. "EPRI supported us in the development of the focused phased-array method of performing guided wave inspection, which identified several low-level category 1 indications on different pipes. As we excavated some of the pipes for mitigation, we were able to validate the information in the EPRI guided wave report by comparison with the pipe itself. This gave us the assurance we needed to continue using the pipes in their present condition. The information gained was extremely valuable in helping us satisfy Nuclear Regulatory Commission extent-of-condition regulations."

For more information, contact Mike Quarry, mquarry@epri.com, 704.595.2668.

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 go to Program Cockpits.

Transportation Electrification: A Technology Overview (1021334)

This detailed overview of the commercial rollout of plug-in vehicles describes the key vehicle and infrastructure technologies and outlines a number of potential roles for electric utilities to consider when developing electric transportation readiness plans. These roles can help utilities to demonstrate regional leadership in planning for transportation electrification, to support customer adoption of plug-in vehicles and charging infrastructure, and to minimize system impacts from vehicle charging.

Engineering-Economic Evaluations of Advanced Coal Technologies with Carbon Capture and Storage—2011 (1022025)

This report presents a current picture of technology, cost, and performance trends for advanced fossil power plants, with and without CO_2 capture. The evaluation summarizes results from recent studies and provides context with discussion of regulatory and economic drivers. The report updates the status of CO_2 capture technology development, summarizes EPRI results for retrofit of CO_2 capture and compression technologies, and tabulates plans for demonstrations of emerging technology options.

Absorbents for Mineral Oil Spill Cleanup (1022150)

Residual mineral oil from electrical equipment spills is often removed by using ground surface application of absorbent materials such as clays, sawdust-like products, silica-based products, and various organic industry by-product materials. This study compares competing absorbent materials, with the goal of realizing cost savings by lowering life-cycle cost—from purchase, storage, handling, and application through final disposal.

Functional Requirements for Electric Energy Storage Applications on the Power System Grid (1022544)

This report describes functional requirements of energy storage connected to the power grid for several applications: grid management at the substation and on the distribution system and storage to integrate larger-scale variable renewable energy installations. The requirements developed in this project provide a common basis on which manufacturers and utilities can evaluate the needs and specifications for storage in these applications.

EPRI Fukushima Daini Independent Review and Walkdown (1023422)

EPRI conducted a detailed "walkdown" inspection of the Fukushima Daini Nuclear Power Station in May 2011 to provide technical input on sustaining safe shutdown and to assess the effects of the March earthquake and tsunami on the station. The observations in this report represent independent input that can be used to confirm or augment understanding of the station's condition. The report also includes a number of short- and long-term recommendations, most of which have been implemented or are planned for development by Tokyo Electric Power Company.

Nuclear Generating Station Containment Monitoring Feasibility Study (1023465)

An EPRI feasibility study evaluated the use of advanced pattern recognition (APR) for on-line monitoring of the containment vessel at an operating nuclear generating station. APR technology shows promise for screening tendon strain data and detecting anomalies that may indicate degradation. This application and the data produced demonstrate that advanced monitoring techniques are feasible for long-term surveillance of passive nuclear plant assets.

Inspection Guideline for Wet Flue Gas Desulfurization Systems (1023487)

The U.S. utility industry has recently discovered a new, fast-growing form of corrosion in the absorber vessels of relatively new flue gas desulfurization (FGD) systems. This guideline provides recommendations for both cleaning and inspecting the stainless steel vessels and includes background information on wet FGD systems, absorber materials, and the corrosion damage mechanism. The guideline is illustrated with more than 70 detailed photographs showing where corrosion is found, what types of corrosion may be encountered, and what tools can be used to evaluate the corrosion.

PRE-SW Electric and Magnetic Fields Workstation (EMFW) 2011, Beta (1024528)

EMF Workstation 2011 software allows a user to create a computer model of transmission lines, distribution lines, buswork, and substation equipment and then calculate electric and magnetic fields produced from these sources. The workstation can also calculate audible noise from parallel transmission lines and evaluate EMF mitigation scenarios to reduce the effects of the magnetic and electric fields. The software will run on Windows XP, Vista, and 7.

Ireland's Ideal Conditions for Electric Vehicles

Paul Mulvaney, *Managing Director, ESB ecars*

Photo courtesy of ESB ecars.

Ireland is an island, off an island, off the mainland of Europe. It has no automobile industry and is not particularly wealthy—maybe not the most obvious location to start an electric vehicle industry!

However, Ireland has many natural advantages:

- A single network company (The Electricity Supply Board [ESB] is the nation's only distribution system operator.)
- A smart grid
- Massive wind penetration (The target is 42% of energy from renewables by 2020.)
- Limited distance between cities (Intercity driving is achieveable through fast charging en route.)
- Home ownership greater than 80% (Most people have a dedicated private parking spot.)
- A moderate climate (The climate is ideal for batteries.)

The Irish government has set a target for 10% of all transportation to be electric by 2020. ESB has been tasked with making this a reality through the ecar Ireland Programme and is rolling out a nationwide charging infrastructure across Ireland, including the supporting IT systems. The two key drivers of the government policy are the requirement to reduce national emissions and the desire to reduce dependence on imported oil. A spin-off benefit will be increased employment and enterprise opportunities.

For a successful national program, it is necessary to take a holistic approach. It cannot be about just the cars or the infrastructure or the electricity or the systems. It must be about the entire user experience and the value proposition being offered.

The ecar Ireland Programme is really about "sustainable transportation." It is about generating, transmitting, and distributing sustainable electricity and using this to power transportation.

It is critical that this new technology be understood and deployed in an interoperable and standardized manner. ESB ecars' multidisciplinary team is working on all aspects of the technology, including the electricity infrastructure, the cars, the connectors, and the communications and IT systems. For the first time, the electricity and automotive industries are merging in a very real manner. In the near future, energy will flow both to and from ecars over the distribution system, creating benefits for both drivers and system operators. Smart charging will have many benefits for the electricity system, supporting load shifting, peak lopping, and virtual spinning reserve. The impact of integrating electric vehicles on the distribution system is being assessed as part of the ESB/EPRI Smart Grid Demonstration Project.

ESB ecars is developing a system that will allow any supply company to deliver electricity to any driver through any public charge point at any time. This is what Eurelectric has described as the Integrated Infrastructure Model. The business systems being developed will support the payment for energy and settlement of real-time charge events with the electricity wholesale market.

To successfully implement a program of this nature, numerous stakeholders must be brought together: the automotive sector to design, develop, and supply cars; technology companies to develop the infrastructure; IT and communications specialists; research institutions to understand user behavior and requirements; and government to provide support and incentives. ESB is participating in a number of international R&D projects to help with this interaction. This new industry is leading to new partnerships and ultimately to new opportunities.

The success or failure of the introduction of ecars to a market will come down to the value proposition on offer to the customer. The benefits—both tangible and intangible—must outweigh the costs in terms of price and customer uncertainty. The challenge is for all of the players to work together to ensure that the value proposition makes sense and that the decision to switch to e-mobility is an easy one for the customer to make.

The introduction of sustainable transportation through ecars will provide many benefits for the environment, the economy, utilities, businesses, and of course drivers. Electric vehicles are a very real manifestation of where the "smart economy" meets the "green economy" for the benefit of all.

For more information, visit www.esb.ie/ecars; Facebook.com/ESBecars; www.youtube.com/ESBecars.

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