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A BLUEPRINT FOR THE HOUSE OF THE FUTURE

ALSO IN THIS ISSUE

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Table of Contents

A Blueprint for the House of the Future

EPRI Works with Builders and Utilities on Advanced Energy Communities

By Chris Warren

Brandon De Young's family tree makes him particularly well suited to conceive and build the California house of the future. On his maternal side, De Young is a third-generation housebuilder in California's San Joaquin Valley, where his grandfather began constructing dwellings during the state's post–World War II economic and population boom. His paternal grandfather worked his way up from elevator operator to vice president at San Francisco–based utility Pacific Gas and Electric Company (PG&E).

Given this family intersection of energy and housebuilding, it's no surprise that De Young—executive vice president of De Young Properties—is a leader in the multifaceted effort to advance zero net energy houses in California, and possibly all across the world.

In Clovis, California, a city just east of Fresno, De Young Properties has built the largest community of single-family zero net energy houses in California. Known as De Young EnVision at Loma Vista, the 3,300-acre development is the result of a collaboration with EPRI, PG&E, and BIRAenergy.

Watch a video of EPRI's Ram Narayanamurthy discussing research on advanced energy communities.

On the surface, De Young EnVision appears ordinary. The 36 houses are exactly what one would expect in a tidy California suburb, with floor plans boasting nearly 4,000 square feet and upwards of seven bedrooms.

The future is in the details. Tesla rooftop solar systems offer capacities ranging from 5 to 9 kilowatts. Houses are constructed using highly energy-efficient building envelopes, materials, and insulation, cooled and heated with electric heat pumps, and wired for electric vehicle charging. The sealed building envelopes combine with effective air filtration systems to keep indoor air clean.

“Most buyers notice the indoor comfort, solar systems, lower energy bills, and better indoor air quality,” said De Young.

A house in the De Young EnVision community in Clovis, California. Photo courtesy of De Young Properties.

A Collaborative Project

De Young’s interest in building zero net energy houses is as much a response to the market as it is a commitment to sustainability. “Zero net energy is a natural extension of an important housing trend in our area,” said De Young. “Here in the Central Valley, energy bills are high and it’s hot. Air quality is bad and everyone knows it. Consumers want efficiency for lower energy bills, more indoor comfort, and clean indoor air.”

With assistance from EPRI, PG&E, and BIRAenergy, De Young Properties determined the right mix of technologies for zero net energy, decarbonization, affordability, and attractiveness to local house buyers. One point of discussion was whether to replace natural gas cooking with electric alternatives. De Young determined that most consumers prefer natural gas and that electric induction cooking wouldn't make sense as a standard offering. It is offered as an option.

The initial response to De Young EnVision has been overwhelmingly positive: 30% of the houses offered in the first phase were purchased their first weekend on the market in late 2017.

PG&E is incorporating lessons from De Young EnVision into its customer programs, electrification efforts, and other opportunities to support customers. It's also using what it has learned to help evaluate grid integration needs.

EPRI's role will continue after all the houses are occupied. "Our research will quantify the benefits and impacts of near-all-electric, smart, and energy-efficient houses and communities, such as reduced CO_2 emissions, increased customer choice, and energy savings," said Ram Narayanamurthy, an EPRI principal program manager. "We want to understand the economic and technical feasibility of developing communities like this one."

Advanced Energy Communities: Integrating Numerous Technologies

The De Young EnVision project is part of a larger EPRI effort to help develop *advanced energy communities*. This term encompasses communities that integrate multiple customer resources, such as energy efficiency, demand response, connected devices, energy storage, solar or other on-site generation, electric vehicles, and other electrification technologies. They are intended to advance social and utility goals such as decarbonization, grid hardening, and grid support while enabling comfort, convenience, and affordability for customers. Zero net energy is one example.

EPRI is assisting in the technical aspects of numerous advanced energy communities in California and beyond. EPRI worked with Southern California Edison (SCE) to help develop zero net energy neighborhoods in Fontana and is assisting with a project in Irvine to construct all-electric, zero-carbon, multi-family houses. The Fontana community has already demonstrated the favorable economics of combining solar and energy efficiency. It also provides insights regarding how customers want advanced energy technologies to work in the background, improve comfort, and reduce costs.

Other benefits emerged as well. "Fontana is located in a very windy area, and customers like that the houses' good insulation reduced the noise from outside," said Narayanamurthy. "They like that the houses felt stable and didn't have things shaking around. Inside, the temperature is very even without any drafts or cold spots, creating a Zen environment."

In all these projects, EPRI provides technical assistance on the selection of technologies, monitors the communities' energy performance and impacts, and brings collaborators together. "We bring together builders and utilities to help develop new housing concepts that meet the needs of house buyers," said Narayanamurthy. "It's in the true spirit of EPRI as a public benefits research organization."

A Trend with Momentum

California utilities and builders face the common need to understand the impact, feasibility, and appeal of zero net energy communities. The state's ambitious greenhouse gas reduction goals aim to cut emissions to 1990 levels by 2020 (a reduction of about 30%), followed by an 80% reduction from 1990 levels by 2050. The state's Long-Term Efficiency Strategic Plan established a goal for all new houses to be zero net energy by 2020, and the state has committed that all new public buildings be zero net energy by 2025 and all new commercial buildings by 2030.

California isn't alone in pursuing zero net energy buildings. The European Union set a target that all new houses be "nearly zero" net energy by 2021.

The broader concept of advanced energy communities also is gaining ground. EPRI has been working with Southern Company in Alabama and Georgia to monitor advanced energy communities that incorporate numerous customer resources (such as high-efficiency HVAC systems, more efficient construction, heat pump water heaters, solar, and storage) and enhance utility infrastructure with microgrids. These efforts can enable new utility services that increase customer satisfaction.

The growing, mainstream interest in advanced energy communities could not be foreseen just a few years ago. "The first zero net energy house I was aware of was built in San Jose in 2011, and the builder spent an extra $100,000 to achieve it," said Peter Turnbull, who leads PG&E's Zero Net Energy Program.

De Young EnVision adds to a growing number of advanced energy communities demonstrating practicality and affordability for house owners and builders today. According to Turnbull, PG&E has worked with Habitat for Humanity to build zero net energy houses for low-income residents at no additional cost relative to the organization's base models.

Results and lessons from EPRI's work with its collaborators in Clovis, Irvine, and elsewhere are revealing ways to drive down costs. "EPRI, PG&E, and other utilities are working with builders and innovating least-cost methods of high performance in these houses," said Turnbull. "There are lots of ways to do it, and these projects help provide the quickest way to get there."

Understanding Grid Impacts

While housebuilders can use advanced energy communities to test new technologies and demonstrate the comfort and convenience of ultra-efficient houses, utilities can gain a better understanding of potential grid impacts.

"We participate in these demonstrations not only to test the technologies," said Jerine Ahmed, a senior engineer with SCE's Emerging Products Group. "We also look at the impacts of these buildings on the electric grid and how to mitigate them so that we can still provide reliable, safe, and affordable power."

A recent study by SCE on grid impacts of the Fontana community raised an important question: Would extensive zero net energy development across its California service territory impact the utility's traditional distribution planning? Traditionally, the utility used air conditioning loads as the primary driver for calculating expected system peaks. The study suggested that load profiles of zero net energy communities may require new approaches for determining peaks, along with infrastructure investment. For example, communities with substantial solar capacity produce more energy through the day as the sun shines and have a steep load ramp in the evening as solar generation decreases. The resulting net load profile, known as the duck curve, could require new ways of operating the distribution system and energy storage to manage the peak loads. Electric vehicle charging could also be an important factor in future load profiles.

Based on the Fontana experience, SCE gained a better understanding of potential impacts on switches, relays, and other feeder equipment. It found that customer-sited battery energy storage, when configured correctly, provided emergency power backup to customers. But the ability to reduce grid impacts was limited because the battery capacity (6.5 kilowatt-hours) was not sufficient to significantly reduce peak loads. Future research could evaluate how larger battery size could help optimize residential energy use with changing grid conditions (for example, use less energy during peak demand). Fontana can also provide insights on how distribution standards might need to be modified to accommodate more zero net energy communities.

“We are still collecting and analyzing the data on these facilities,” said Ahmed. “Fontana was the first zero net energy neighborhood we worked on. In the past it was one or two houses at a time. This experience helps us design incentive programs and work effectively with builders.”

In Irvine, SCE and EPRI will investigate zero net energy in townhouses and condos, in which many urban southern Californians live. “This project will be an all-electric community,” said EPRI’s Narayanamurthy. Besides highly efficient insulation and HVAC systems, the 44 residential units will have electric heat pumps, water heaters, appliances, and cooktops.

While new lessons about grid impacts and technical challenges will emerge in Irvine, the needs of housebuyers will likely remain constant. “Customers want these technologies to make a difference on comfort, cost, and convenience—and otherwise operate in the background,” said Narayanamurthy.

Key EPRI Technical Experts

Ram Narayanamurthy

Facing the Storm

Mobile Substations, Cross-Country Customer Support, Wind Farms, and Other Success Stories from the 2017 Hurricanes

By Tom Shiel

In just three days, Hurricane Harvey dumped 51 inches of rain on Houston in late August 2017, flooding a third of the city. Crews from local utility CenterPoint Energy deployed dozens of air boats, amphibious vehicles, and drones to survey the damage. Overflow from two levies flooded a substation in the Spring Branch district, and the crews needed a quick solution to restore power.

"We were near George Bush Park, which had never flooded like that before, when we found a church parking lot that was above water," said Taylor Stuckey, CenterPoint construction and quality assurance coordinator. "It was the perfect spot to put a mobile substation because it was near the flooded one."

With the blessing of a priest at the church, CenterPoint placed its Memorial Mobile Substation on the property to serve residents and businesses while the permanent substation was restored.

"We set up temporary transmission and distribution poles and rerouted the power around the existing substation," said Kenny Mercado, CenterPoint senior vice president for electric operations. "The mobile substation has operated for more than seven months while CenterPoint rebuilds and upgrades the substation."

According to Mercado, mobile substations have been part of CenterPoint's resiliency strategy for years. The utility keeps them on hand for natural disasters and other circumstances.

"If we're building a substation and the load is growing quickly, we will bring in a mobile substation until we can complete the construction," he said.

The value of mobile substations is among dozens of lessons and insights to emerge from electric utilities' response to deadly 2017 hurricanes. At an EPRI Research Advisory Committee meeting last October, utility executives discussed their hurricane response in detail and compared notes on different approaches.

“We brought together people with a variety of experiences and perspectives to share what they’ve learned, ask questions, and explore how to move forward as an industry,” said EPRI Senior Project Manager Robin Bedilion.

This article discusses the experiences of three companies: CenterPoint, Pacific Gas & Electric (PG&E), and EirGrid.

Photo credits from left to right and top and bottom.

CenterPoint and Alabama Power crews inspect the flooded Memorial Substation in Houston's Spring Branch district. Photo courtesy of CenterPoint.

CenterPoint and Alabama Power crews inspect a flooded neighborhood in Houston's Spring Branch district. Photo courtesy of CenterPoint.

Flooding at Memorial Substation in Houston's Spring Branch district. Photo courtesy of CenterPoint.

After Hurricane Irma, PG&E helped FPL handle customer calls. In this photo, FPL trainer Santiago Herrero (right) provides guidance to PG&E's Anjanette Jones. Photo courtesy of PG&E.

CenterPoint built this mobile substation in a parking lot to serve customers while a nearby flooded substation was restored. Photo courtesy of CenterPoint.

Before Tropical Storm Ophelia made landfall in Ireland, EirGrid's National Control Centres preemptively curtailed more than a gigawatt of wind capacity in the southwest region. Photo courtesy of EirGrid.

More than 20 PG&E employees took customer calls for FPL after Hurricane Irma. Photo courtesy of PG&E.

A wind farm in Ireland. Photo courtesy of EirGrid.

CenterPoint: Digital Technologies in Action

More than a million CenterPoint customers lost power because of Hurricane Harvey. CenterPoint's response relied on 2,200 employees, 1,500 contractors, and mutual assistance from seven states for a total of more than 350,000 hours.

Mercado said that his company's Intelligent Grid technology avoided more than 40 million outage minutes during Hurricane Harvey. Hundreds of power line monitoring devices, remote switches, smart meters, and other automation equipment helped crews locate outages and speed repairs.

"It gave us a faster start," said Mercado. "When you digitize your grid, you see things in real time that you never could see before. It allows us to efficiently monitor our system for real problems, prioritize our resources, and efficiently recover from our damages. It also allows us to prepare for communications with customers and other stakeholders."

"Digital smart metering was probably the most important advancement. It worked incredibly well," he said. "We were able to use the remote capabilities of meters even when the streets were flooded and not passable. The meters enabled us to communicate with customers about outage conditions during and after the storm. We were reading meters, turning them back on, and getting lights back on."

Fifteen drones were equipped to assess damage and provide information on working conditions facing crews at hundreds of locations—from flooding to broken poles to downed wires. The drones' infrared sensors helped to identify weakened or damaged power lines and equipment requiring further inspection.

CenterPoint's Power Alert Service provided customers with text and email updates on outages and estimated restoration times. The utility also used Facebook, Instagram, and other social media to communicate with customers.

"We were well-prepared and well-drilled," said Mercado. "We understood our roles and responsibilities. Our Incident Command Structure worked very well."

PG&E: Customer Service for Florida Power & Light

During natural disasters, utilities' mutual assistance programs help them restore customers' electric service quickly and safely. On September 8, 2017, as Hurricane Irma approached Florida, PG&E sent crews to assist Florida Power & Light (FPL) with grid restoration. After the hurricane made landfall a few days later, PG&E received an unusual request.

"We were on a call with FPL leadership, and we asked if there was anything we could do to help out on the customer side," recalled Chris Zenner, who directs PG&E's Residential Customer Team. "They asked if we could take customer calls."

This had never been done before, but PG&E accepted the challenge, enlisting its IT department to brainstorm a solution.

"We converted a training room in our Sacramento customer contact center into an FPL call center," said Zenner. "We wiped the PG&E software off the computers and installed FPL software."

FPL had to ship virtual private network (VPN) tokens to enable PG&E call-takers to access the Florida utility's real-time outage information. PG&E's IT team worked with FPL to troubleshoot technical problems.

"We asked for volunteers because we knew they were going to have to work weekends," said Zenner. "We received an overwhelming response—more than we needed."

On September 15, an FPL trainer flew to Sacramento and oriented PG&E's 22 volunteers, with support from PG&E trainers. "The volunteers were ready to take calls the next day," he said.

From September 16–22, they responded to more than 4,650 customer calls, with the utility's IT team assisting as needed.

"A lot of the customers had been without power for many days," Zenner added. "Many of the calls were about wires down. Customers were asking, 'When are you coming out?'"

PG&E call-takers responded to customer inquiries using FPL's real-time outage data.

"With mutual assistance, we often think of sending crews to restore power," Zenner said. "But how do you help with customer support? It was important to get the right people involved from the beginning—the people who can make the important decisions. That was the biggest lesson learned. On day one, we didn't have the right decision makers in the room, but by day two, we did."

PG&E developed an effective process for handling outage calls for another utility. This included setting up computers, assembling and training staff, and resolving IT issues. The experience also pointed to the importance of deploying IT and training personnel as early as possible.

"In the future, if hurricanes are forecast and we offer to help with customer calls, we're going to have a trainer fly out here early and have PG&E staff positioned so that we're ready to go on day one," Zenner said.

EirGrid: Wielding Ophelia's Wind

On October 16, 2017, tropical storm Ophelia hit southwest Ireland with record-breaking winds.

A concern for transmission grid operator EirGrid was managing Ireland's significant wind power capacity before, during, and after the storm's winds hit the island. At high wind speeds, wind turbines automatically shut down to prevent damage—and a sudden, large loss of generation can adversely impact grid balance. EirGrid's National Control Centres can control most of the country's wind farms remotely. Before the storm made landfall, the centers preemptively curtailed more than a gigawatt of wind capacity in southwest Ireland (about 25% of the country's total installed wind capacity). As the storm moved across the island, wind turbine curtailments were lifted in the south and applied in northern regions. Grid operators ramped up reserve generation from conventional power plants to balance the system's production and demand.

They also needed to anticipate system demand. System load was lower than normal because of distribution system faults and industry and school shutdowns. This resulted in high voltage in some parts of the transmission system, which EirGrid staff successfully mitigated using the wind farms' voltage control capabilities.

"A big insight from Ophelia relates to the use of renewables during extreme weather," said EPRI Technical Leader Adrian Kelly. "It is essential that remote control is available to control renewable energy resources. With remote control, EirGrid could accommodate significant wind generation even at high wind speeds. Curtailing wind generation just before storm landfall helped to avoid a sudden loss of energy. EirGrid then used the curtailed wind energy to balance the system and navigate demand forecast uncertainty. Grid operators also used wind farms to control transmission system voltage."

Communication was integral to EirGrid's response. The company's Emergency Communications Team held 12 meetings on the day of the storm to discuss weather, system status, and staffing. With more operators than normal in the control centers, it was critical to define roles and authority clearly.

Resiliency Research at EPRI

EPRI research initiatives to enhance grid resiliency and recovery during and after major storms include:

- Drone inspections for storm response. Surveying field experience, identifying the value and limitations, field-testing technologies, and informing decisions for specification, acquisition, and application of technologies.
- Tool for prioritizing resiliency investments. Developing a tool that enables utilities to estimate the reduction in outage risk per dollar spent for a given resiliency strategy.

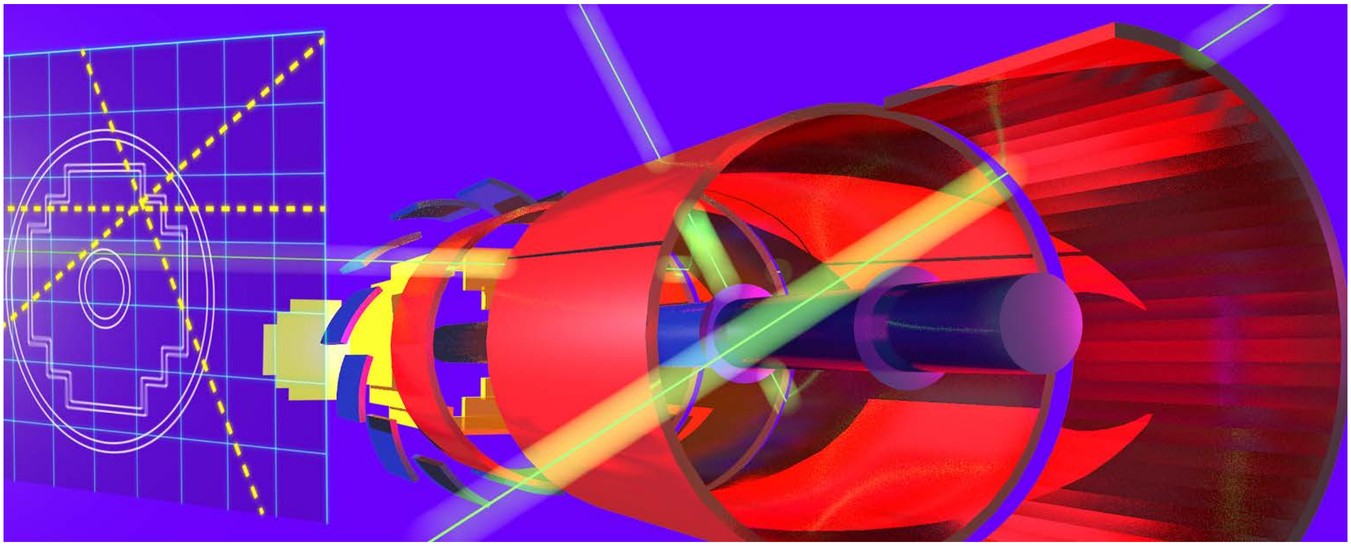
- Overhead distribution design for resiliency and reliability. Identifying, testing, and refining resilient designs for overhead structures.
- Role of microgrids and advanced energy communities in resiliency. This includes work with the U.S. Department of Energy and the California Energy Commission.

"We must continue to develop the research and technologies to make responses to these events even more effective and efficient," said EPRI's Bedilion. "An important takeaway from our October meeting was that addressing these issues requires continuing the spirit of cooperation and collaboration among our utility members."

Key EPRI Technical Experts

Robin Bedilion, Adrian Kelly, John Tripolitis, Dexter Lewis, Arindam Maitra

‘Push a Button and the Work Gets Done’



EPRI Examines Robotics and Automation for Nuclear Plant Decommissioning

By Brent Barker

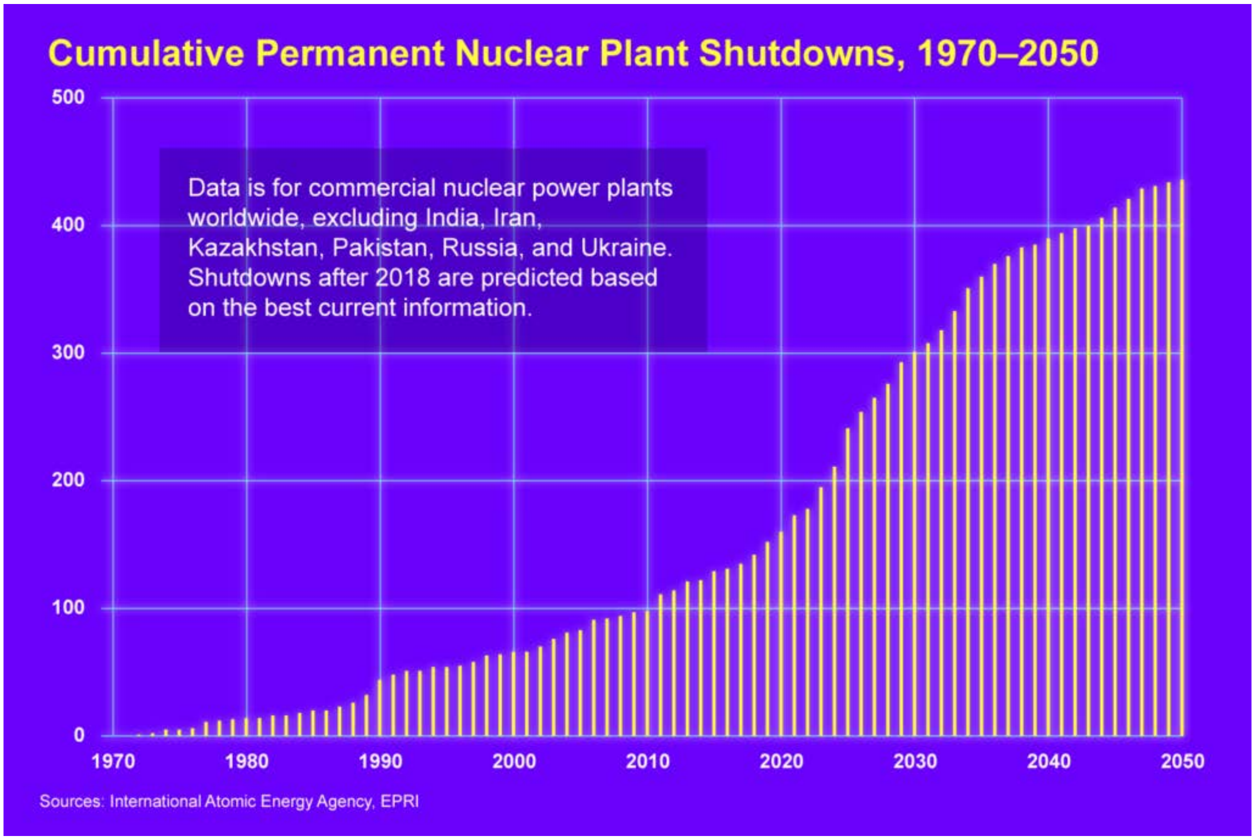
The Resident Farmer Scenario describes the ideal endpoint of a fully decommissioned nuclear plant site when it is sold to new owners. The structures have been removed and radiation reduced so that a family can reside year-round, breathe the air, till the soil, grow and eat crops, and drink the groundwater without hazard. The U.S. Nuclear Regulatory Commission’s (NRC) radiation dose threshold for this scenario—25 millirem per year per person—is less than 10% of the average American’s annual exposure. This endpoint is achievable for many plants given the right set of decommissioning technologies and techniques.

Decommissioning procedures today are precise, effective, and safe but highly labor-intensive, typically taking 10 years at a cost of roughly $80 million per year for each plant. There’s increasing interest among plant owners, operators, and regulators in accelerating the process through automation and robotics without sacrificing safety.

Decommissioning work is expanding significantly worldwide as many plants approach the end of their license in countries that do not permit extensions. Some countries are mandating early plant retirement, while in others market pressures are driving plants to close—with some single-unit facilities unable to compete with lower cost natural gas and renewable generation.

Of the 111 nuclear plants that have been shut down globally, only 13 have been completely decommissioned, and 38 are being dismantled. Sixty have yet to begin decommissioning. Some of these have been placed in safe storage for decades until adequate funding is available for decommissioning. Often, units are put in safe storage when they share sites with units that remain in operation. This is because it’s more efficient to decommission all the units at once.

Based on current announced energy policies, as many as 10 or more plants may be permanently shut down per year in each of the next 10 years. The global decommissioning queue is expected to grow to more than 200 plants at a total cost of roughly $160 billion (see graphic).



Ranking Key Tasks to Reduce Time and Cost

EPRI's Decommissioning Program is focusing on the use of technology to reduce the time and cost of decommissioning while maintaining safety. "Several years ago, we assembled experts to assess all the major tasks in decommissioning," said EPRI Technical Executive Rick Reid. "For each of the 54 tasks, we asked them where to focus R&D. We explored questions such as, can you use a robot instead of a human being to perform this task? If so, what are the benefits? Can the task be automated? How much time would that save? While most of the tasks do not warrant the use of robotics or automation, we found that several tasks do and offer significant potential savings in time and cost."

"I believe that we're going to find real advantages with automation," said Reid. "We currently use semi-robotic systems for many tasks, with skilled operators directing them. Since a lot of this work is predictable and programmable, we can automate it. Ideally, an operator pushes a button and the work gets done. That's how we can complete tasks faster and with less radiation exposure to the operators."

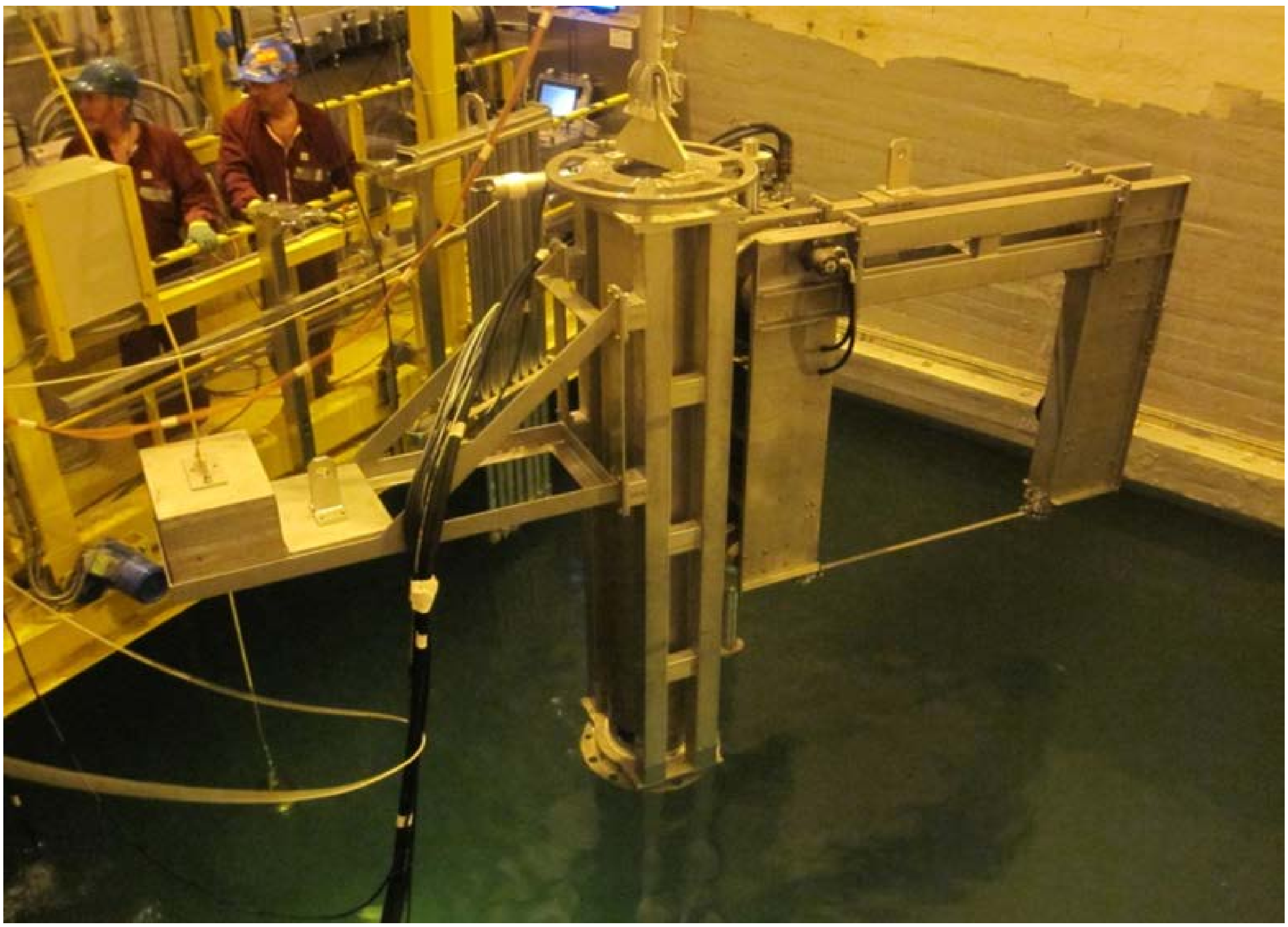
Among the several tasks that offer the greatest potential benefit from automation, Reid and EPRI Principal Technical Leader Rich McGrath are investigating two: the segmentation of a reactor's internal components (one of the first tasks in decommissioning) and the site characterization survey (one of the last tasks). Both of these are critical path tasks.

Cutting Reactor Materials for Packaging

Early in decommissioning, the spent nuclear fuel is removed from the plant's reactor pressure vessel, leaving a framework of two-and-a-half-inch-thick, highly irradiated stainless steel plates that must be cut up and packaged in a disposal container.

With the current approach, the framework is submerged in a pool of water. On a bridge above, technicians operate an underwater camera system and cutting tool, following a precise cutting plan and protocol so that the pieces can be moved and packed efficiently into an underwater disposal container.

"This takes about a year, so the operators are getting a fair amount of radiation exposure," said Reid. Although this exposure is monitored and well within regulatory limits, cutting reactor materials typically is one of the tasks that results in the most exposure during decommissioning.



At the Jose Cabrera Nuclear Power Station, workers on a bridge use remote control to lower a band saw into a spent fuel pool containing the reactor's internal components. The saw will make pre-determined vertical or horizontal cuts. EPRI is developing a system to automate this cutting process so that workers do not need to be present.

From Reid's perspective, this task is a fit for semi-automation. "Rather than stationing someone on the bridge using what's essentially a joystick, we could position someone remotely, watching what is happening on a screen and intervening if necessary."

This requires a precise map of the structure and precise cutting and packaging plans so that the pieces nest together tightly in the container. "A computer could be used to make the cuts and complete the task," said McGrath. "Technology available today can 'look' at the component underwater, determine exactly where to cut to create the right puzzle piece for the container, and execute the cut."

Cutting is slow. Most is performed mechanically, with disc saws, band saws, and shears.

"We're looking at faster technologies, including laser cutting, which essentially vaporizes the material," said McGrath. EPRI is evaluating the cutting rate of an underwater fiber laser. Another technology, the arc saw, has shown significantly faster cutting rates relative to mechanical cutting.

Additional testing, scale-up, and demonstration of these processes will be critical for adoption by an industry that subjects new technologies to rigorous vetting.

Site Characterization Survey

The site characterization survey takes a year or longer. "You have to show that radioactivity is below allowable levels throughout the site, which could range from tens to hundreds of acres," said Reid. "If you leave any buildings in place, you have to evaluate all the surfaces. It is a tremendous amount of work."

"I was at Connecticut Yankee during the decommissioning," said McGrath. "About five years before completion, we started the survey with the outlying land. As the plant was getting cleaned up, we moved closer in. It can take a year or more just to survey the buildings."

In the plant area, most survey work is done by hand, requiring a great deal of equipment. Technicians scan walls with handheld radiation meters, and others use meters attached to extenders or mounted on boom lifts. "At one plant, the decommissioning team built a scaffolding to the top of the containment building, and people climbed up and scanned the surface with handheld meters," said McGrath.

Opportunities for automation are numerous. "The technology is there. Imagine a mobile robot, like a golf cart or a small tractor, surveying the empty land with a radiation meter and using a global positioning system to trace an exact path," said McGrath. "Drones can be used to reach inaccessible areas."

"Because you know what needs to be done and where, these surveys can be easily programmed on a grid," said Reid. "You push a button, and the work gets done, faster and more safely."

EPRI is engineering the systems for both cutting reactor components and surveying sites. The next steps are working with fabricators on prototypes, conducting laboratory and plant demonstrations, and transferring to industry.

Reid is optimistic that automation and robotics will reduce the time and cost of decommissioning while improving worker safety. "The process now averages about 10 years. As companies get more experience and new technologies are brought on board, it's likely they'll get this down to eight years. If you really execute these things well, you can probably get it to six years. That's significant when you consider that every year saved provides millions of dollars in potential savings."

International Decommissioning Collaboration

Stakeholders in several countries are seeking collaborative R&D opportunities to improve decommissioning technologies and techniques. “In particular, companies in France are interested in pooling resources and ideas,” said McGrath. “The equipment is very expensive, and you want to make sure it works well before you put it into a radioactive field application.”

Recently, SHARE—an international group whose members include research organizations, utilities, waste disposal site operators, and the International Atomic Energy Agency—has formulated a roadmap for eight technology categories and made preliminary assignments for each. “EPRI is likely to be involved in all of them,” said McGrath.

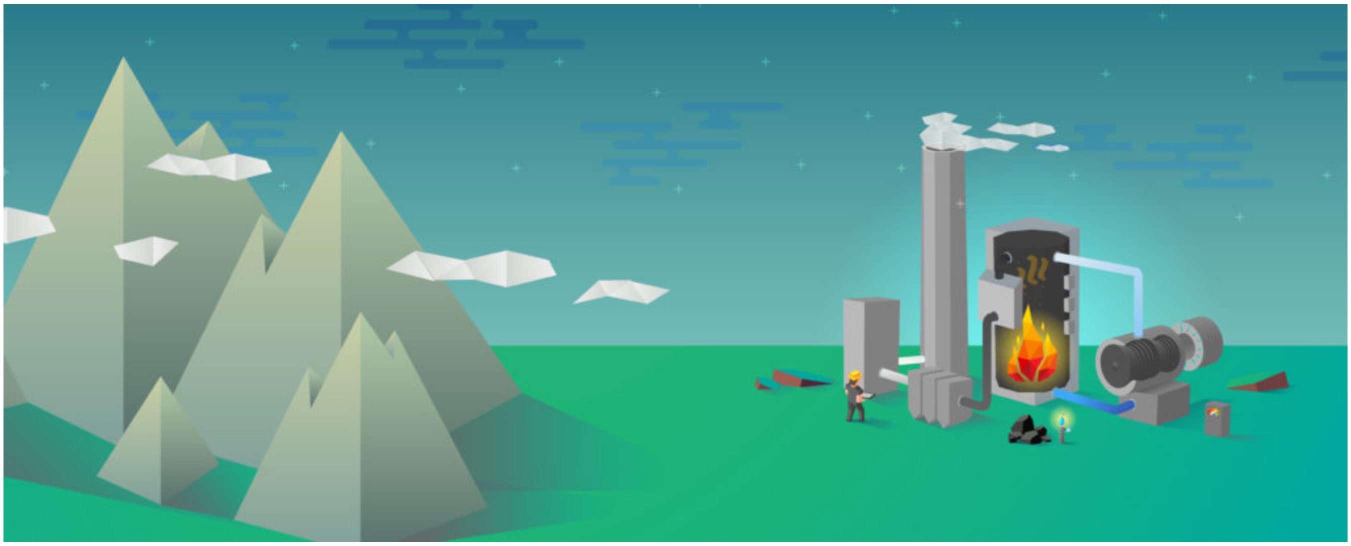
For each technology category, SHARE team members will identify the areas with the greatest potential for improvement. These will be developed as collaborative research projects.

“We’re very excited about the potential for SHARE,” said Reid. “By sharing resources and information, we can make great progress and avoid duplicating efforts.”

Key EPRI Technical Experts

Rick Reid, Rich McGrath

From Baseload to Flexible Operations



EPRI Examines New Technologies, Techniques, and Tolerances at Coal Plants

By Brent Barker

With growing renewable generation, low natural gas prices, and other market forces, coal plants designed for baseload operation increasingly operate in flexible modes such as:

- **Low-load operation or turndown:** Operating at reduced output.
- **Load-following:** Following the ups and downs of the daily load cycle, causing the temperature of key components to fluctuate hundreds of degrees in a short period.
- **Cycling:** Turning off the plant daily, followed by a "hot start" in a few hours.
- **Extended layup:** Turning off the plant for weeks to months. In regions with significant wind power, for example, operators may schedule extended layups during spring and fall when winds are high and sustained and load is not elevated by air conditioning or heating demand.

Flexible operations can take a physical toll on coal plants in many ways. For example, as the temperature of the steam in a plant's turbine rises and falls, metals expand and contract, leading to fatigue. This is compounded as thin and thick metal parts expand and contract at different rates. Environmental controls optimized for baseload operations may be less effective at lower loads and lower temperatures. During shutdown and layups, water can gather where steam usually flows, leading to pitting and corrosion in metal components.

Research by EPRI, utilities, and others indicates that the aging coal fleet can adapt to flexible operations with new technologies, new techniques, and a willingness to experiment with new operational practices.

Toward Technical Solutions

"Flexibility is so important that every program in EPRI's Generation Sector is examining it in some way. For example, the Boiler and Turbine Steam and Cycle Chemistry program (Program 64) is looking at novel treatments that produce protective coatings for components; the Boiler Life and Availability Improvement program (Program 63) is investigating how to better manage fatigue; and the Steam Turbines program (Program 65) is studying steam flow and the effects of low-load operation," said EPRI Senior Program Manager Mike

Caravaggio. "The 15 utility members in our Mission Profile Working Group [see box at end of article] are gaining a holistic view of all the impacts of various flexible modes."

One way to minimize fatigue and creep damage is to keep steam temperatures as constant as possible through all operating modes. "Changing a plant's power output can move heat absorption around the boiler," said Caravaggio. "This can cause tubing to run hotter than it was designed for and cause components to change temperature rapidly. Managing these temperature changes requires systematic monitoring and control involving numerous systems."

"A key lesson that we've drawn from years of flexible operations work with utilities is that turndown is always better than cycling on and off," said EPRI Principal Technical Leader Merrill Quintrell. "With turndown, you can avoid a lot of operations and maintenance problems."

This interactive graphic describes EPRI research to enable flexible operations at a typical coal plant.

During flexible operations, plants must continue to comply with regulatory limits for nitrogen oxides, sulfur dioxide, mercury, and particulate matter. “Load changes have a significant impact on how post-combustion control equipment performs,” said EPRI Senior Program Manager Tony Facchiano. “In low-load operation, the temperature of the flue gas exiting the boiler is reduced, which can adversely impact the performance of the selective catalytic reduction reactor.”

These reactors are designed to operate within a specific temperature range to avoid formation of ammonium bisulfate, which can clog the catalyst’s pores. Recent EPRI research has demonstrated that the temperature at which ammonium bisulfate forms can be lower than what has been observed in previous assessments. This means that in some applications, minimum operating temperatures may be safely lowered, although caution needs to be exercised.

To protect steam turbines, boilers, and other equipment from moisture during layups, EPRI has developed procedures that include deploying dehumidification systems. To inhibit corrosion in water/steam cycle equipment during layups, EPRI and several utilities demonstrated the effectiveness of film-forming products in field tests.

Experimenting in the Field

In working with utilities on flexible operations, EPRI has had considerable success experimenting with procedural changes, re-examining traditional margins, and testing new operating tolerances.

“When a utility asks to work with us, we first find out which flexible modes are relevant,” said Quintrell. “Then we examine plant operational and design data and identify possible problems with instrumentation and controls. After those are fixed, we run a protocol to test new tolerances. We take the unit down as low as it can go, then ramp it up as fast as it can go, then run it through cycling routines.”

This experimentation serves as a stress test to identify the unit’s limits. Based on the performance data, EPRI makes three tiers of recommendations. Tier one includes procedural and operational changes, such as taking a specific pump out of service or opening a particular bypass valve. Tier two involves relatively small capital investments such as new instrumentation and valve replacements. “These are things that may cost a few thousand dollars—small investments for large gains,” said Quintrell. “Level three recommendations are typically expensive capital modifications that would enable the operator to overcome significant design challenges with the plant.”

Typically, utilities implement tiers one and two, but not three. “Utilities are unlikely to commit large amounts of capital to a legacy asset that may not be in service in 10 years,” explained Quintrell.

One power plant dramatically improved its turndown capability by changing certain procedures and replacing the pyrometer in the boiler with a flame scanner. “The pyrometer only measures heat and does not indicate which burners are operational—information that is particularly important when the plant goes to an extremely low load,” said Quintrell. “EPRI recommended the flame scanners because they provide a picture of burner conditions. More precise control of the burners, along with the procedural changes, enabled operators to lower the plant’s load by roughly 70%.”

Operators at a plant with two 1,300-megawatt units were constrained from operating each unit below 800 megawatts because it would be below the optimal speed range for the two boiler feedwater pumps in operation. The units would “lug” the way a standard shift car does when it needs to be downshifted. “We suggested a simple solution—take one pump out of service,” said Quintrell. “Their first reaction was, ‘We can’t do that, it’s against our operating procedures.’ Then they agreed to experiment. It worked and enabled each unit to turn down to 550 megawatts.”

This inexpensive procedural change is now standard for turndowns. “At this facility, the utility can take an additional 500 megawatts off the grid without having to shut down any units, saving about $2 million per year in avoided startup costs.”

EPRI’s wide-ranging research plans for flexible operations include new materials and coatings for components, advanced component manufacturing, new ways to manage hotspots and fatigue, improved sensors to track component condition, innovations in inspection, enhanced tools to assess damage, and more.

“Our objective is to help the industry successfully transition from baseload to flexible operations by the mid-2020s,” said Caravaggio.

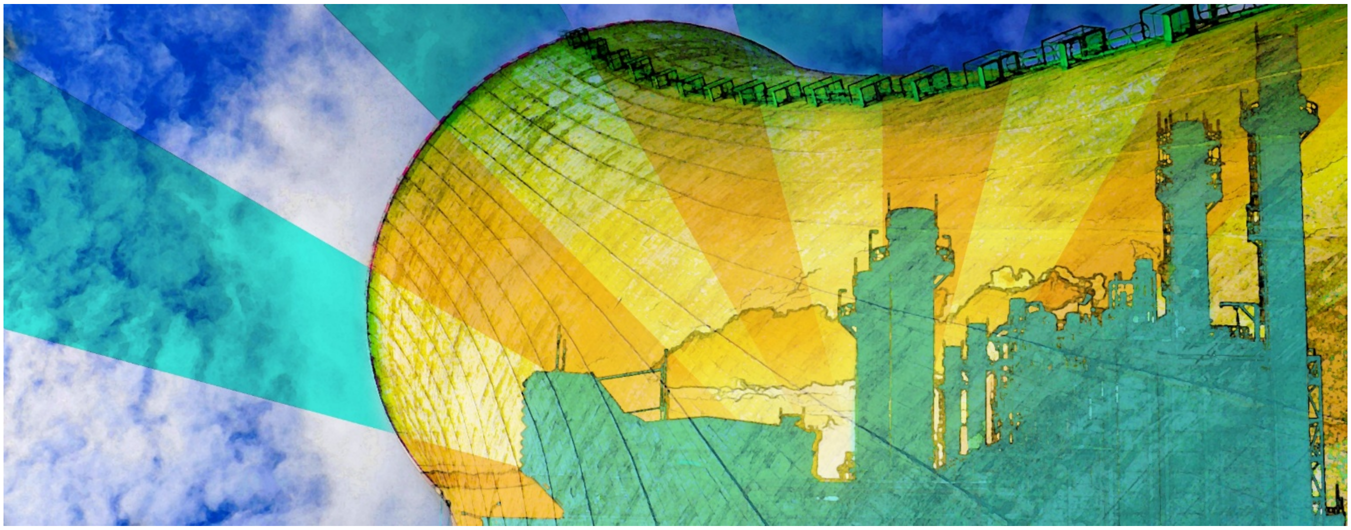
Mission Profile Working Group

The 15 power companies in EPRI’s Mission Profile Working Group are developing a comprehensive online resource to help power plant operators identify and address impacts of various flexible modes. The beta version draws on industry knowledge about power plant design, vulnerabilities with systems and components, field-proven solutions, and more. While it is currently available to members of the working group, in 2019 EPRI plans to expand access to all utility members of its Generation research sector.

Key EPRI Technical Experts

Mike Caravaggio, Tony Facchiano, Merrill Quintrell

Cooling Research Heats Up



New R&D Center Accelerates Development of Power Plant Cooling Systems That Use Less Water

By Chris Warren

With a growing global population and many competing uses for limited water resources across the United States, wise use and conservation are more important today than ever before. To accelerate development of new technologies that help reduce water use and improve efficiency in the power generation sector, Southern Company, its Georgia Power subsidiary, and EPRI have established the Water Research and Conservation Center at Plants Bowen and McDonough-Atkinson.

"A commitment to impactful research and development is shared by all of our operating companies, including Georgia Power," said Rebecca Osteen, research engineer for Southern Company. "Water use is a long-term, strategic issue for power generation, and it is important that we invest in and develop technologies that require less water without compromising service for customers."

About 43% of all thermoelectric power plants in the United States use once-through cooling systems. These withdraw water from rivers, lakes, and other nearby sources, circulate it to absorb heat from steam in condensers, and discharge nearly all of the heated water back to its source.

About 42% of thermoelectric plants in the U.S. are cooled by open recirculating systems—more commonly known as cooling towers. Before returning water to nearby sources, these systems reduce the volume and temperature of water by recirculating it through cooling systems to dissipate most of the heat to the atmosphere through evaporation. Open recirculating systems withdraw much less water relative to once-through cooling systems and are widely used in new power plants, but they consume more water because of evaporation in cooling towers. According to an EPRI study, recirculating cooling systems in the U.S. consume an average of nearly 3 billion gallons per day.

Dry cooling and hybrid cooling systems require further development to be as cost-effective as open recirculating systems. According to the U.S. Energy Information Administration, fewer than 2% of U.S. power plants use these technologies.

"Most cooling systems at power plants rely on fresh water to be available all the time," said EPRI Project Manager Jeffery Preece. "In the U.S., that translates into about 40% of all freshwater withdrawn, which is about the same as for agriculture. The difference is that power plants with open recirculating systems return about 96% of that water to its source. That said, EPRI recognizes the importance of power generation resiliency and anticipates that challenges with freshwater availability will become more common."

Georgia Power's Plant McDonough-Atkinson. Photo courtesy of Georgia Power. [click to enlarge]

Accelerated Research Needed

Entrepreneurs, scientists, and diverse organizations—such as the U.S. Department of Energy, the National Science Foundation, and the Asia Pacific Economic Cooperation—are conducting R&D to reduce cooling technologies' freshwater consumption without significantly impacting power plant efficiency. Innovation is progressing, but commercializing the technologies has proven challenging. A research venue is needed to accelerate technology progression from pilot stage to commercial operation.

"There's a lot of early-stage research in small-scale laboratory settings," said Preece. "This work needs to be applied on a much larger scale to simulate power plant conditions and identify pathways for commercialization."

In addition to developing the most effective technologies, success depends on incorporating them into operating power plants. "When we integrate and optimize these technologies, we need to account for the complexity associated with plant components, systems, and processes," said Preece. "The technologies need to provide more efficient cooling without increasing a plant's operational costs or hurting performance."

A New R&D Center to Fill the Void

The Water Research and Conservation Center aims to support innovators of cooling and heat transfer technologies in the early stages of development. Cooling technologies are the large systems that cool the steam turbine exhaust in a condenser, while heat transfer technologies are systems and components that enable more efficient heating, cooling, or both. The new center is an expansion of the Water Research Center at Georgia Power's Plant Bowen, which has been operating for five years. Construction is underway at Georgia Power's Plant McDonough-Atkinson, and the expanded center is expected to open in early 2019.

The new center's design draws on a comprehensive review of research and development initiatives around the world, including facilities used by manufacturers of power plant cooling and heat transfer technologies.

"We have done a global tour of R&D facilities and are integrating the best practices and making improvements of our own," said Preece.

The center will simulate power plant conditions at a scale significantly larger than laboratories, though much smaller than a full-scale power plant. Tests will incorporate plant infrastructure such as shell-and-tube heat exchangers, cooling towers and systems, a climate control and simulation system, and access to cooling water.

"We will have equipment that simulates various heat transfer processes in a power plant, cooling and heat transfer loops for testing new technologies, and control loops for comparing the performance with that of today's open recirculating and dry cooling systems," said Preece. "The scale is small enough to enable accurate testing and large enough so that the results can be reasonably applied to operational power plants."

Coatings, Materials, Chemicals, Sensors, Systems, and More

As the center's operator and facilitator, EPRI will work with technology developers and utilities to develop test plans and protocols, drawing on its extensive R&D in the following areas:

- Use of alternative water sources in power plants
- Reuse of water in open recirculating systems
- Technologies that reduce evaporative water losses in open recirculating systems
- Technologies that improve the efficiency and reduce the cost of dry cooling systems
- Hybrid systems that combine the cost and performance of wet cooling with the water efficiency of dry cooling

"Power plants have a long history of using water that is degraded and would otherwise require extensive treatment for agricultural, municipal, or industrial use, and we expect this to become more common," said Preece. "For example, when desalination plants use traditional reverse osmosis to treat brackish groundwater, only 50% to 75% of the resulting water is usable for drinking water. The remaining 25% to 50% is wastewater. Power plants are exploring the use of that wastewater as an alternative to fresh water or groundwater."

Initially, the center's research plans include investigation of:

- Coatings and nanomaterials applied to condenser tubes and cooling towers to improve heat transfer
- Chemical treatment to prevent or mitigate corrosion of cooling system components
- Systems, materials, sensors, and techniques to reduce the volume of water needed for cooling

When considering new heat transfer and cooling technologies, plant operators need answers to site-specific questions about installing new equipment and retrofitting existing systems. "You have to think about the technology from the perspectives of mechanical design, fabrication, and installation," said Preece. "Is this a system that stands alone or does it integrate with other systems? If it has to be integrated, what are the technical and economic considerations? Do you have a robust supply chain, accurate mechanical design, and realistic installation plans?"

EPRI will provide utilities and technology developers with guidance on these issues. By simulating power plant conditions and scenarios often not accounted for in early-stage R&D, the center will help developers better understand deployment challenges and implement solutions for timely commercialization.

"The technology aspect could be straightforward, but the economics, design, and integration are not," said Preece. "The integration is key to having the technology do what it is supposed to do."

The center plans to host numerous utilities and developers and test diverse new technologies at a larger scale than previous research. According to Osteen, these attributes were a big draw for Southern Company's participation. "This effort helps us understand challenges that utilities across the country are facing," she said. "In the western U.S., utilities have put in more expensive air-cooled systems that have hurt plant efficiency. We haven't had to do that, but we want to identify technologies now so that we have practical, viable options in the future."

"The center will help developers and utilities identify accelerated pathways to commercialization," said Preece. "We intend to facilitate research on many aspects of cooling systems while advancing the science and technology."

Key EPRI Technical Experts

Jeffery Preece

Viewpoint—Electrification: A Big Idea Is About to Get Much Bigger

As one of the most versatile forms of energy on the planet, electricity can be generated from many resources and used to provide many services safely and efficiently. It is the backbone of the digital economy. As an idea, electrification's application and benefits are continuing to increase. As the electric supply becomes cleaner, efficient electrification can reduce society's overall emissions. It can also improve energy efficiency, economic efficiency, water use efficiency, grid utilization efficiency, productivity, and safety.

Mike Howard, President and Chief Executive Officer, EPRI

Today, in the energy sector as a whole, I see efficient electrification, especially electric transportation, becoming a "Big Idea"—and one poised to get much bigger as energy sector stakeholders arrive at a common understanding of its potential to change the energy landscape.

As I write this in the early summer, EPRI is finalizing the agenda for Electrification 2018, our first conference and exposition to bring under one roof electrification's stakeholders, innovators, and business interests. Personally, my enthusiasm for this event is rooted in my leadership at EPRI, in my career as a researcher, and in the satisfaction I take in a hands-on approach to technology.

It Takes a 'Big Tent' to House a Big Idea

Consider the exposition, which will host nearly 100 companies and organizations covering virtually every aspect of electrification. Those attending can engage with people driving innovation and commercial opportunities in energy storage, advanced industrial processes, commercial building automation, zero net energy developments, and electric vehicle charging. (One company offers a charging station that you can take with you when you travel.)

We see significant interest in electrification and agriculture, with emphasis on indoor agriculture. But participants also can interact with people who have helped a traditional "outdoor farm" employ renewables in a microgrid configuration that includes the farm's homegrown software innovations.

Also in the exposition will be innovators and developers working on systems architecture and platforms for the "Internet of things" and Blockchain. These provide opportunities to understand more clearly how transactional and energy management systems are instrumental in electrification's central role in more dynamic and integrated energy networks.

This just scratches the surface of what is offered by this event (and more important, electrification overall). Looking beyond the conference itself, the key point is that electrification's scope is much bigger than most people have realized. By bringing into focus the full breadth of its application and benefits, we can achieve faster, more integrated progress.

Digging Deeper

In broadening the scope of our thinking, we need to dig deeper as we go. Pre-conference workshops explore industrial processes, lean manufacturing, the foodservice industry, building electrification and decarbonization, and transportation.

Breakout sessions provide in-depth discussion in five tracks: transportation, industrial and commercial/residential technologies, the regulatory/policy landscape, and understanding electrification's cost and benefits.

C-Suite Perspectives

Through the conference's three plenary sessions, we are framing executive perspectives on "the big idea" of electrification, the technology involved, and its economic aspects. These perspectives encompass utilities, venture capital, transportation (personal, industrial, and mass transport), industrial facility construction, environmental stakeholders, and regulators. These sessions will rely heavily on conversation among the leaders present, and we expect them to spark a great deal of conversation in the breakout sessions and in the exposition hall.

I think it is no exaggeration to say that electrification is rapidly outgrowing its traditional definition and its familiar boundaries. We expect the discussions, the scope of research, and the technological progress to grow. EPRI is actively encouraging the broadest possible participation as we go forward. The Big Idea is about to get much bigger.

Mike Howard

President and Chief Executive Officer, EPRI

In Development

Navigating the 'Moving Parts' of Grid Telecommunications

EPRI Helps Utilities Manage and Operate Complex, Tiered Networks

By Brent Barker

Telecommunications (telecom) for the modern grid is developing into a complex, multi-tiered network-of-networks that can manage and integrate diverse technologies and facilitate the rapid, seamless flow of information.

At the top of the grid telecommunications hierarchy are wide area networks (WAN). These are the most comprehensive networks and can extend beyond the utility's service territory. As the telecom backbone, they support smaller field area networks (FAN), which in turn support neighborhood area networks (NAN) and even home area networks (HAN). Each network can employ multiple technologies.

"There are many moving parts," said EPRI Technical Executive Tim Godfrey, who leads EPRI's telecommunications research. "Telecom options and preferences can change rapidly. Ten years ago, for example, utilities were thinking that home area networks would be connected through a smart meter, but now the customer is more likely connecting through their broadband provider."

Telecommunications can potentially enable greater levels of distributed generation, distribution automation, substation automation, and alternative telecom business models, but technical and operational challenges remain.

"The utility industry's telecommunications networks may be extremely heterogeneous, with all kinds of different technologies tied together to facilitate the transfer of information and data in the most efficient manner," said Godfrey. "Our job is to research the common threads and collaborative issues that affect the whole industry. These include not only technical options, but operational issues, such as speed, spectrum access, integration, reliability, standards, and performance."

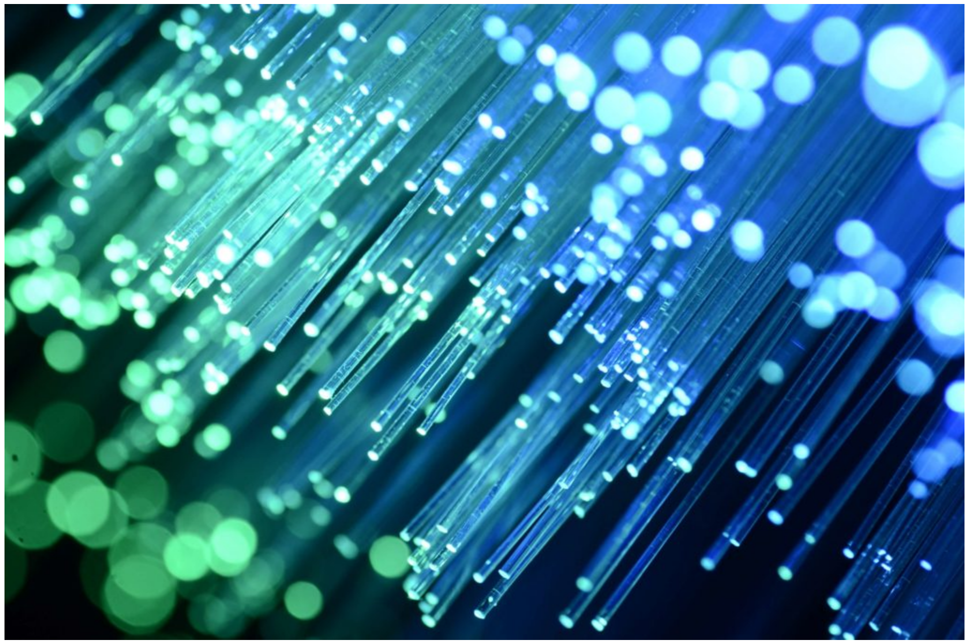
EPRI's telecommunications research focuses on three areas:

- **Wide area networks**. Operational excellence and strategic vision for the WAN. Critical areas include the transition from legacy systems to packet-based networks, the convergence of IT and OT Networks, and new approaches for strategic fiber deployment.
- **Field area networks**. Evaluating and selecting optimal FAN solutions. Critical areas include evaluating various wireless technologies in both private and public spectrums and analyzing usage trends in the unlicensed wireless spectrum.
- **Network management and planning**. Critical areas include automation, metrics, and cyber security.

Strategic Fiber in Wide Area Networks

According to Godfrey, the most common technology used for WANs today is fiber-optic cable.

Fiber material is cheap. While the cable is expensive to install (either overhead or underground), it typically lasts more than 30 years. It is often deployed atop transmission lines in optical protective ground wire.



"Fiber is the gold standard for telecom," said Godfrey. "Every strand is as fine as your hair, strong as steel, and supports multiple gigabits per second. It's fast-lane, reliable, and durable. In areas of devastation I've seen the fiber cable holding up the pole." In 2017, EPRI published two reports (see Strategic Fiber Handbook Phase 1 and Phase 2) that evaluate ways to improve deployment and operation of fiber.

Some utilities have explored offering aggregated fiber services to homes. "Most utilities ultimately backed away because the business model puts them into the highly competitive Internet service provider market," said Godfrey. "We probably won't see many utilities providing a full-service model of electricity, Internet, telephone, and TV because of the potential for stranded assets. Regulations can also prohibit investor-owned utilities from entering other markets such as Internet services."

One of EPRI's goals for 2018 is to research the potential benefits and challenges involved in expanded use of fiber in a 5G world.

Wireless in Field Area Networks

EPRI is building on its Field Area Network Demonstration, which focused on wireless connectivity from substation to the distribution grid. "We developed a platform that utilities could use to test long-term reliability and performance of various wireless systems," said Godfrey.

Conclusions from the demonstration include:

- A mix of wireless technologies is necessary for various applications.
- The private licensed spectrum is the optimal choice for many applications, but cost is high and availability limited.
- New opportunities are emerging with commercial cellular technology, including Mobile Virtual Network Operators (MVNO), Private Virtual Network Operators (PVNO), and private LTE networks.

For 2018, EPRI plans to examine trade-offs between private wireless and commercial cellular networks and evaluate usage trends in unlicensed spectrum. "Deploying a private network is a challenge for utilities, since global operators own most of the suitable wireless spectrum and are unlikely to sell their spectrum," said Godfrey. "In some cases, they may lease some of their underutilized or underperforming spectrum to utilities or others."

Improving Network Security

Telecommunications network security is a concern for grid operators. “We’re looking at how the telecom network can take advantage of software-defined networking,” said Godfrey. “In the old days you would have a rack of routers and switches, with patch cables going everywhere. To change your network, you had to physically go in and change things. With software-defined networking, you issue some software commands, and you’re on a different network. During a grid cyber attack, it may give us the ability to reconfigure a telecom network quickly and automatically.”

Key EPRI Technical Experts

Tim Godfrey

Innovation

Illuminating a 'Black Sky'

EPRI Examines Backup Communications to Restore the Grid After a Disaster

By Chris Warren

The term *Black Sky* event has an appropriately ominous ring to it. It refers to natural or human-caused disasters that could result in large-scale disruptions of critical infrastructure for a month or longer. Examples of Black Sky events are powerful hurricanes, earthquakes, and high-altitude electromagnetic pulses.

Last year the Electricity Subsector Coordinating Council, which convenes federal government and power industry leaders, pinpointed Black Sky event response as worthy of additional research. In particular, the council wanted to investigate emergency communication systems that could operate during extended outages to support repairs and service restoration.

"The council is made up mostly of utility CEOs, and its R&D committee identified Black Sky communications as a priority," said Matt Wakefield, director of information, communication, and cyber security research at EPRI. "Along with the North American Transmission Forum, the council asked EPRI to investigate the requirements for an emergency communication system that would be needed if a utility lost its primary and backup control systems—energy management systems and SCADA."

Recent natural disasters such as Hurricane Maria point strongly to the importance of emergency communications. Without voice and data communications, utilities face extreme challenges in dispatching crews, making repairs, load balancing, and other critical activities. The power industry needs effective, reliable tools to meet emergency communications requirements.

EPRI's research builds on the North American Transmission Forum's "Spare Tire" initiative, which identified reliable voice and data communications along with 10 other operational capabilities that would be required to restore grid operations after the loss of control systems. EPRI is documenting requirements for emergency communications during a Black Sky event, assessing technologies to meet the requirements, examining interoperability standards, and developing a technology test plan.

Communication equipment must be able to function in worst-case scenarios—including a Category 5 hurricane, an earthquake of magnitude 7 or greater, a cyber attack or terrorist attack on the power grid, and a high-altitude electromagnetic pulse attack or geomagnetic disturbance.

EPRI examined the capabilities of various voice and data communication technologies during different simulated Black Sky events. "We analyzed how these technologies would likely perform based on their requirements, specifications, and other characteristics," said Wakefield. "For example, the type of satellite phones most utilities have on hand for emergency communications would not work during a high-altitude electromagnetic pulse, but could be well-suited for natural disasters."

Researchers are evaluating the emergency communication capabilities of technology using high-frequency radio and near-vertical incidence skywave propagation. Because these can provide long-distance communication without expensive infrastructure, the military has long used them in remote locations.

In the lab and the field in Manhattan, EPRI and Con Edison evaluated whether the system could interface with a SCADA system used for testing (and not grid operations). The voice component worked fairly well. Data communications worked in the lab but not in the field, revealing the need for additional investigation of shortwave radio's reliability. The investigation highlighted the necessity to rely on multiple technologies to address different Black Sky scenarios.

"It is unlikely that a single technology can work for all solutions," said Wakefield. "We want to map those technologies to operational requirements under specific Black Sky scenarios."

EPRI's report details the strengths and weaknesses of numerous voice and data technologies. Interviews with utility executives revealed that utilities have prioritized Black Sky communications with state and regional emergency operations centers. EPRI will continue to develop and test communication technologies and may collaborate with the U.S. Department of Homeland Security, which has a shortwave radio program with participation from many local emergency and first-responder agencies.

EPRI presented the results of its Black Sky research to the R&D committee of the Electricity Subsector Coordinating Council. EPRI's next step is to develop specifications for a Black Sky communications system and use these specifications to guide vendors and technology providers as they develop systems. EPRI also plans to develop a guide for utilities on system operations and maintenance.

An important question still under consideration: How much preparation is appropriate for these unlikely events? "It's a discussion of how much investment and effort we should put into it," said Wakefield. "It's a critical question to answer because even though these are low-frequency events, they can be very high impact."

Key EPRI Technical Experts

Matt Wakefield, Tim Godfrey, Jay Herman

R&D Quick Hits

Lab Studies Examine New Technique for Assessing Nuclear Plant Cables

EPRI is investigating a promising technology to evaluate the condition of low-voltage cables in nuclear plants—an historically difficult task.

Low-voltage cables serve important roles in nuclear plant operations, powering components, control systems, and communications. Many low-voltage cables were manufactured in the 1970s and 1980s, when most U.S. nuclear plants were built. As plant operators consider extending licenses beyond 30, 40, or 60 years, it is important to assess cables' remaining useful life and to determine necessary repairs and replacements.

Today, technicians primarily use visual inspection and nonelectrical techniques. These require cable samples or direct access to cables, which is not always feasible. The best available electrical test method, frequency domain reflectometry, is performed at cable terminations. It can detect and locate anomalies but cannot determine whether anomalies result from degradation or bent or twisted cable.

Because prior EPRI research determined that dielectric spectroscopy is effective for assessing a cable's overall condition, researchers wanted to determine whether it could be combined with frequency domain reflectometry to pinpoint areas of severe degradation requiring repair or replacement.

In the laboratory, they applied dielectric spectroscopy to three cable samples (both shielded and unshielded) before and during accelerated thermal aging, and the method showed promise in detecting degradation. Building on these results, EPRI plans to lab-test more cables, develop diagnostic metrics, and field-test naturally aged cables.

R&D Quick Hits

'Super' Coatings Perform Well in the Lab and Field

Power delivery components may soon have a new shield against ice and dirt accumulation. In laboratory tests, superhydrophobic and icephobic coatings performed well on insulators and conductors, pointing to their potential to enhance grid reliability and reduce maintenance costs.

EPRI evaluated 12 manufacturers' coatings, selecting the four that performed best for laboratory and field testing. In the laboratory, the coatings were applied to glass and aluminum samples, sections of new and aged aluminum/steel conductors, and porcelain insulators. They were subjected to high humidity, temperature cycling, ultraviolet light, salt fog, and electrical and mechanical stresses. All coatings effectively reduced dirt contamination and ice formation, and none failed. They were shown to have a life expectancy similar to that of currently used coating technologies. Aged and new components with coatings performed comparably.

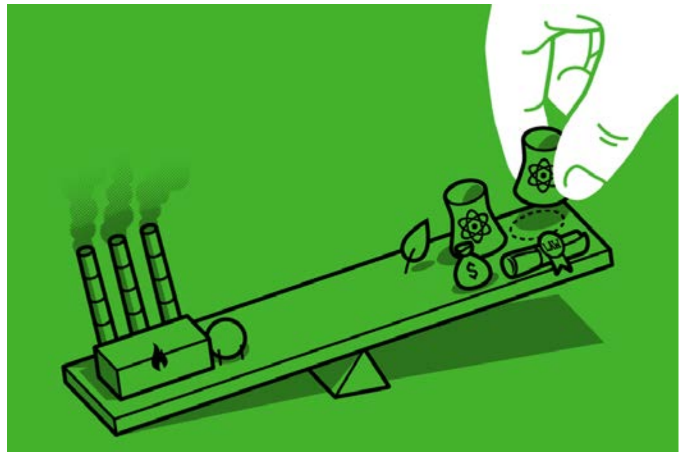
Field tests still in progress at six utility sites in New York, Georgia, Alabama, Wisconsin, and North Dakota have demonstrated that the coatings can be applied effectively to in-service transmission and distribution insulators and conductors. In some tests, the coatings have shown enhanced protection against contamination. Leakage currents have not increased on insulators.

Additional data on field performance are still needed. Emerging coatings and surface modification techniques show greater promise and need lab and field assessment.

Workers apply coatings to a transmission conductor during an EPRI field test.

R&D Quick Hits

What's the Future of Nuclear Power in the United States?



According to an EPRI modeling study, a combination of reduced capital costs, additional revenue streams, and stringent climate policies could enable significant deployment of advanced nuclear power technologies.

Low natural gas prices have challenged the profitability of nuclear power in the United States, stalling new deployment. Yet many power industry stakeholders see an important future role for nuclear plants with zero-carbon emissions, given their long operating life and reliable production during weather extremes.

Using EPRI's U.S. Regional Economy, Greenhouse Gas, and Energy (US-REGEN) model, researchers investigated how natural gas prices, various policies, technology innovation, and other variables could affect nuclear power's competitiveness. Key insights:

- Deploying new reactors in the United States likely would require lower cost technology options; carbon pricing or other climate policies that support zero-carbon generation; or supplemental revenue from sales of process heat, hydrogen production, or other services.
- Given continuing low natural gas prices and no new climate policies, significant innovation would be needed in nuclear reactor technologies and business models for extensive deployment.
- Nuclear generation could face additional competition as a result of innovation in other dispatchable low-carbon energy technologies, such as solar, wind, and fossil generation with carbon capture and storage.
- Nuclear power's competitiveness varies considerably with regional characteristics, such as natural gas pipelines, state policies, generation portfolios, and transmission.

The results are relevant to other advanced nuclear technologies (such as fusion) with similar anticipated benefits (low-carbon, dispatchable generation with high energy density) and challenges (high capital costs). EPRI is considering similar analyses for non-U.S. markets.

R&D Quick Hits

Heat Pump Water Heaters: Are They Worth It?

Which is more cost-effective for a house—an electric heat pump water heater (HPWH) or a natural gas water heater? It depends on factors such as climate, system and installation quality, and local energy prices.

An EPRI demonstration of electric HPWHs showed about 50% energy savings relative to traditional electric resistance water heaters. Savings vary based on operating conditions. Efficiency of HPWHs increases in warm, humid surroundings and decreases when water use necessitates electric resistance backup heat.

Relative to natural gas water heaters, HPWHs may or may not be a better deal over the unit's lifetime. One key consideration is the installed cost. According to a 2016 study by the National Renewable Energy Laboratory, HPWHs can range from $2,100 to $3,300 depending on the water tank's capacity. Natural gas water heaters range from $700 for standard units to $4,500 for condensing units. A quality installation may cost more but may improve operating efficiency.

While comparing efficiency of HPWHs and natural gas water heaters is not straightforward (different metrics are used), operating costs can offer a simple comparison. These depend on local energy prices. In California, where average electricity prices are about $0.19 per kilowatt-hour and average natural gas prices are $1.18 per therm, the range of annual operating costs for the HPWH and natural gas water heater are $145–$337 and $111–$182, respectively.

In Florida, where average electricity prices are $0.12 per kilowatt-hour and natural gas prices are $2.04 per therm, annual operating cost ranges for the HPWH and natural gas water heater are $96–$224 and $190–$310, respectively. In Florida's hot, humid climate, an HPWH may provide additional cost savings by helping to cool indoor spaces.

EPRI is evaluating existing HPWHs and is collaborating with a manufacturer on a grid-interactive, high-efficiency HPWH, with plans to test prototypes in early 2019.

R&D Quick Hits

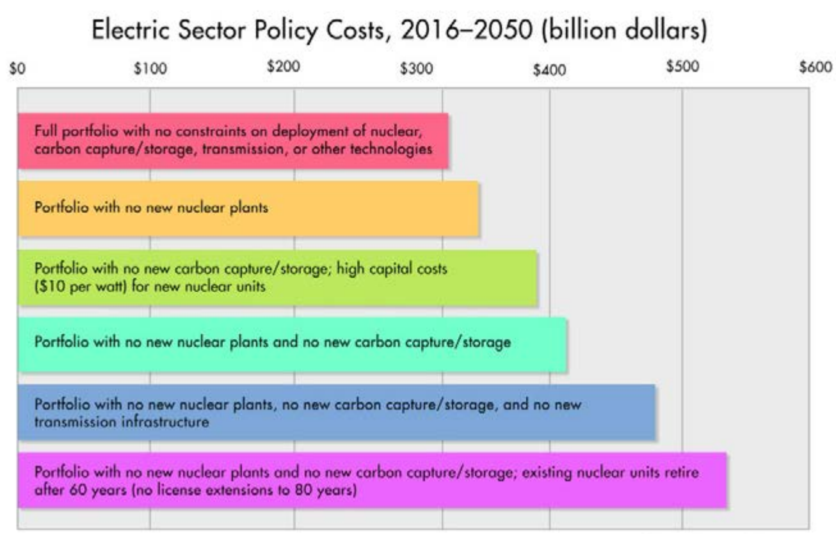
How to Cut Compliance Costs: Innovate

Modeling Study: U.S. Could Save Hundreds of Billions of Dollars with a Full Generation Portfolio

Given a potential stringent carbon policy, the U.S. power sector could reduce compliance costs by about half by deploying broad technological portfolios, according to an EPRI modeling study.

Using EPRI's United States Regional Economy, Greenhouse Gas, and Energy (US-REGEN) model, researchers evaluated a range of portfolios and advanced technology R&D with respect to generation mix, emissions, and power industry costs, for 2016–2050. The analysis considered a hypothetical federal mandate for the power sector to reduce CO_2 emissions by 2050 to 95% below 2005 levels. The study defined "full" technology portfolio to include solar, wind, hydropower, geothermal, natural gas, coal, carbon capture and storage for fossil units, new nuclear plants, extended operations for existing nuclear plants, and biomass.

Compliance costs decreased dramatically as portfolios included more options, with dispatchable low-carbon generation such as nuclear and carbon-capture-equipped fossil units providing significant value. Costs for a full portfolio were more than $200 billion less than a portfolio lacking new and existing nuclear plants and carbon capture and storage (see chart below). R&D on advanced generation technologies drove down compliance costs by another $200 billion, assuming that certain capital cost targets are met.



Based on various technology scenarios, EPRI modeled costs to comply with a federal mandate for the power sector to reduce CO_2 emissions by 95% below 2005 levels by 2050.

EPRI JOURNAL

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