

## Innovation

## A Sunny Forecast

### *EPRI Tool Helps Utilities Prepare for Influx of Solar*

**By Chris Warren**

These days, evidence of the rapid transformation of the electric power system is anything but abstract. GTM Research and the Solar Energy Industries Association (SEIA) report the installation of more than 4,000 megawatts of solar photovoltaic (PV) capacity in the United States in the third quarter of 2016—a nearly 200% increase compared with third quarter in 2015.

To help distribution grid operators accommodate this growth safely, reliably, and efficiently, EPRI and eight member utilities developed a tool that can forecast residential PV adoption in their service territories over the next 10 years. Numerous models can forecast market penetration of products and technologies, but until now none have been PV-specific.

“If you have good forecasts for the timing, location, and speed of PV adoption on particular circuits and can estimate the circuits’ hosting capacity, you can determine how quickly you’ll need to upgrade them to accommodate the PV or whether you can defer investment based on the PV’s ability to serve load growth,” said EPRI Principal Project Manager Nadav Enbar, who helped develop the tool.

With a better understanding of PV adoption rates, utility planners can consider such options as incentives for installations on circuits that can handle the resulting increased two-way power flows.

### **Building a Forecasting Tool**

EPRI used a research approach known as a discrete choice experiment to develop the tool. Researchers identified solar installation attributes that influence consumers’ decisions, including type of financing, location on a utility customer’s roof or community site, greenhouse gas emissions reduction, and cost savings.

The attributes were tested with a focus group and then used to develop questions for surveys administered to more than 2,500 customers in the service territories of the eight participating utilities. The survey’s 28 questions included basic queries about income and residence size along with various solar options. The results were used to build a “choice model” for determining the combinations of attributes likely to drive customer preferences. The PV forecast adoption tool is based on this model.

**“We would like to engage other utilities, survey their service areas, and use the results to make the model more robust.”**

“By pairing the model with ZIP Code–level demographic data from the U.S. Census Bureau as well as historical adoption data, we can also look at how demographics impact someone’s willingness to purchase a solar system,” said EPRI Senior Project Engineer Steven Coley.

The forecast tool also factors in falling solar prices. “We can get a sense of people’s willingness to pay for solar given a set of attributes,” said Coley, who worked on the tool. “You can vary the cost in the future and see how that willingness changes.”

## Improving and Expanding the Forecasts

The eight participating utilities will be the first to use the tool, which incorporates preferences and demographic data from their customers. Based on estimated annual solar-related costs and savings that PV provides for their residential customers, the utilities can determine the likely number, timing, and location of new solar installations, through direct purchase or lease, or as part of a community solar project.

“Based on user-defined costs, savings, and other inputs, the tool can output the number of customers in each ZIP Code that are likely to adopt solar each year,” said Enbar.

After refining the tool based on feedback from these utilities, EPRI in 2017 will release a more generic version for other utilities.

“The generic version will incorporate the same data on customer preferences as the current tool, but will use statewide demographic information rather than ZIP Code–level data for more general solar growth forecasts,” said Enbar. “We would like to engage other utilities, survey their service areas, and use the results to make the model more robust.”

Another potential refinement is to incorporate market data linked to why people adopt solar. “There’s an opportunity to make the tool more robust by supplementing stated customer preferences for potential purchases with data on drivers for actual purchases,” said Coley.

Similar tools may also be developed to forecast the adoption of commercial PV and electric vehicles.

## Key EPRI Technical Experts

Nadav Enbar, Steven Coley

In Development

## A Portable Laboratory for Catalysts

### *EPRI Test Facilities Help Utilities Optimize Emissions Reductions at Coal Plants*

**By Chris Warren**

Selective catalytic reduction reactors are among the most important tools for reducing nitrogen oxide (NOx) emissions from coal-fired power plants. Located between the boiler and air preheater, the reactors use a catalyst material—often a honeycomb-like ceramic substrate—that can eliminate more than 90% of the NOx from a plant's flue gas stream. For optimal performance, ammonia is mixed with the flue gas before it reaches the reactors. The reactors offer an additional benefit: They oxidize mercury so that it can be captured in a coal plant's wet scrubber.

The effectiveness of NOx and mercury removal depends on the formulation and condition of the catalysts, which can last several years before being replaced. Over time, the catalysts' pores can get clogged with contaminants in the flue gas. Utilities typically monitor catalysts by periodically removing samples from the reactors and sending them to a lab for tests. Because it is prohibitively expensive to generate a coal-fired flue gas, labs burn natural gas in testing, and the resulting flue gas does not contain the fly ash present in a coal-fired facility.

"It doesn't have the ash, and that is the question mark," said EPRI Principal Project Manager Tom Martz. "The ash may or may not do some funny things when it comes to the behavior of the catalyst."

#### **Taking the Lab on the Road**

To provide insights on a range of catalyst performance issues, EPRI developed two portable catalyst test facilities that can be set up at a coal power plant in just a few days. They pull a flue gas "slipstream" from the power plant, divert it for testing, and then return it to the plant.

"The portable facilities enable us to test catalyst samples in an operating coal flue gas environment, complete with fly ash," said Martz. "Because the facilities are portable, we can evaluate catalysts at different plants with a variety of coals and operating conditions. We can provide site-specific information for plant catalyst managers."

In their inaugural application in October 2015, EPRI used the facilities to compare the effectiveness of a standard new catalyst with a regenerated one.

"Regenerated catalysts are less expensive than new ones," said Martz. "The utility wanted to know whether the regenerated catalyst was doing its job in terms of reducing NOx and oxidizing mercury. To vet the many replacement options and make informed purchase decisions, plant catalyst managers need independent catalyst performance data collected from operating power plants."

For another utility, EPRI in 2016 conducted an on-site, side-by-side comparison of a more expensive advanced catalyst with a conventional one. "There's no independent data on field performance to decide whether it's worth paying a premium for the advanced catalyst," said Martz. "The portable test facilities are perfect for answering this question."

Because the price and comparatively low emissions of natural gas make it so competitive, many coal plants are being asked to cycle more often and operate at low loads. In late 2016, EPRI used the portable facilities to examine how this affects catalyst performance.

“Operating at a lower load may require selective catalytic reduction reactors to run at lower temperatures, but catalyst vendors set a minimum operating temperature to protect the catalyst,” said Martz. “This can limit the load drop on large coal plants by as much as 100 megawatts, which is huge for utilities in terms of revenue and flexibility.”

Vendors are concerned that ammonium bisulfate may form in the catalyst pores at lower temperatures, potentially impairing catalyst performance. But EPRI research has demonstrated that the temperature at which ammonium bisulfate forms can be lower than what vendors assert.

“Observations during EPRI’s portable facility tests, combined with previous EPRI research, provide greater clarity regarding ammonium bisulfate formation,” said Martz. “They show that the minimum operating temperatures may be safely lowered in many cases. We are now able to give practical guidance to plant managers for operating the reactors at lower loads.”

“Our goal with the test facilities is to inform the industry so that plant managers have more flexibility,” said Martz.

### **Key EPRI Technical Experts**

Tom Martz

## Innovation

## Taking the Heat

### *EPRI Examines Sensors That Can Withstand Harsh Environments in Gas Turbines*

**By Scott Sowers**

EPRI is evaluating more rugged sensors to monitor natural gas turbines and help optimize operations of current and next-generation facilities.

Demand for natural-gas-fired generation is growing in North America, driven by low prices and ease of deployment. Some combined-cycle units are cycling more frequently or operating for more hours than they were designed to operate, challenging reliable operations. This has spurred efforts to enhance monitoring of the performance and condition of online units using sensors that measure various parameters—temperature, fuel flow, fuel pressure, air flow, air pressure, exhaust gas flow, fuel quality, and exhaust gas constituents.

A key consideration: Sensors must be able to withstand temperatures up to 1300°C—and even higher in the turbine’s combustion zone—while providing accurate readings.

“Traditional electronic sensors fail quickly if exposed to high temperatures, so they are not usually viable options for the combustion zone of a gas turbine,” said Principal Project Manager Susan Maley. “We need materials and designs that can sense temperature and pressure changes and other parameters at extreme temperatures for extended periods of time.”

To protect today’s sensors from high temperatures in gas turbines, they are often placed in “standoff tubes” located a certain distance away from areas being monitored, reducing measurement accuracy. The tubes also can lead to false readings as a result of condensation buildup.

One particularly important indicator of gas turbine operations is dynamic pressure. But at high temperatures and pressures, direct measurement is difficult. There are no accurate, commercially available sensors that can withstand combustion temperatures.

Operators often indirectly determine combustion temperature and other difficult-to-measure parameters by making calculations based on easier-to-measure parameters.

“We can back-calculate and make estimates, but these are not as accurate as direct measurements,” said Maley.

### **Scanning the Sensor Technology Landscape**

Researchers outlined measurement needs in the various parts of a natural gas turbine, including the compressor, combustion zone, and turbine. To meet these needs, they identified commercially available and emerging sensor technologies developed for the power generation industry and other industries such as aerospace. EPRI is tracking innovations at organizations such as the Propulsion Instrumentation Working Group, Air Force Research Laboratory, NASA, and the U.S. Department of Energy.

EPRI is looking at advances in wireless micro-sensors the size of a penny, sensors made of heat-tolerant ceramics, lasers that act as sensors, and fiber-optic sensors.

According to Maley, fiber optics are especially promising. “They sense and send signals using light transmission, rather than electronics, so viability in a turbine’s hot zone is a worthwhile research and development effort,” she said.

Correct turbine blade operation is vital, and EPRI is evaluating sensors that measure blade dynamics, which include vibration, strain, clearances, tip deflection, and timing.

“The blades are designed to have some flex. But under certain conditions, their resonant frequencies can become excited, and the blades can break off,” said EPRI Senior Technical Leader Bobby Noble. “This can cause many other blades to fail and lead to a ‘corn-cobbing’ effect on the turbine’s compressor section, which can cost millions of dollars to fix.”

The next step is field evaluations of promising technologies. EPRI also will continue evaluating new sensors in collaboration with the Georgia Institute of Technology. A report on key findings is expected in 2017.

“With better sensors, we can positively impact turbine performance, efficiency, and reliability,” said Maley. “We hope to identify a few options that can benefit the industry and the public through more reliable and less expensive generation of electricity.”

“Just like with personal computers, sensor technology is making the impossible possible,” said Noble. “What once was thought to be too hot or too hard to get to is now possible.”

### **Key EPRI Technical Experts**

Susan Maley, Bobby Noble

In The Field

## Knocking the Dust Off

### *Pressure Wave Cleaning Offers Potential New Option for Power Plants*

**By Sarah Stankorb**

Two workers feed a hose-like lance capped with a plastic balloon into a power plant's heat recovery steam generator (HRSG), maneuvering around tight spaces between tall bundles of tubes caked with yellow debris. Meanwhile, an engineer sitting at a computer at the other end of the lance has mapped out the HRSG on a grid. The computer controls the delivery of an ethane-oxygen mix through the lance to inflate the balloon. When the balloon is positioned at the proper grid coordinates, the engineer ignites the gases inside. The pressure wave rattles the HRSG components with a boom and dislodges debris, which settles to the bottom of the HRSG.

This new process, called pressure wave cleaning, shows promise for reducing plant operational costs and enabling less expensive, more reliable electricity.

#### **Cleaning Tubes: An Important Job**

People who like their music turned up loud have probably noticed their windows rattle with the beat. They're enjoying the vibratory force of a pressure wave, which is similar to that caused by the ignited gases in the HRSG. In this case, the wave vibrates tubes just enough to rattle off debris.

Over time, power plant performance depends on keeping tube bundles clean in both coal-fired boilers and HRSGs. Tubes in HRSGs pick up heat from the plant's combustion turbine for reuse in spinning steam turbines. When those tubes become fouled—by ammonia, sulfur, or rust—the resulting back pressure can damage the turbine and increase heat rate, leading to lost energy and higher generation costs.

According to EPRI Program Manager Bill Carson, tube bundles typically need cleaning after a few years in service, and traditional methods include chemical cleaning and groom ice cleaning. Many plants' permits prohibit disposal of wastes from chemical cleaning, and groom ice cleaning requires significant work hours and resources to build scaffolding and complete the job. Considering that each approach can have drawbacks, EPRI is examining the effectiveness of pressure wave cleaning to provide utilities with another option to consider.

Pressure wave cleaning requires no labor-intensive scaffolding construction. Swiss company Bang & Clean developed the technology and in 2015 successfully tested it on an HRSG at ESB's Dublin Bay Power plant in Ireland. GE has licensed the technology in the United States.

EPRI has played a key role in bringing the technology to the United States and facilitating industry collaboration. In 2015, ESB personnel presented on their field experiences at EPRI's Boiler Reliability Interest Group meeting attended by dozens of utilities, and the group recommended that EPRI spearhead a project to test the technology in the United States. In subsequent tests in an HRSG at TVA's Southaven Combined-Cycle Plant, inspections by TVA and EPRI indicated that no component damage occurred.

#### **Successful Demonstrations in the Southeast**

Jacob Pursley is an operations technician and HRSG system owner at a power plant in the U.S. Southeast. A few years ago, a round of groom ice cleaning helped the plant to reduce problems with back pressure. "We pulled out a few tons of debris from each unit, and we thought, 'Hey, we're good to go,'" recalled Pursley.

But after three months offline during a rainy fall and a major outage, fouling again accumulated on the HRSG tubes, and back pressure increased to unprecedented levels. “I was concerned that if we went back in there with ice cleaning, had all the people in there, put up all the scaffolding, racked up all the man hours, and banged up all the tubes again—would we get the results we needed?”

After reviewing EPRI data on pressure wave cleaning, Pursley and the plant’s management team decided to test GE’s PressureWave Plus™ technology. The previous round of groom ice cleaning required 20 work days (10 days, two shifts each day) to clean three modules in each HRSG. Using pressure wave cleaning, the team also cleaned a fourth module that could not be reached by scaffolding, completing the entire job in 14 work days (one shift each day)—including two days for a vacuum truck to remove debris.

“The safety side of it is that nobody is inside the HRSG when it’s going on, and you have none of the hazards with constructing scaffolding inside the HRSG,” said Pursley.

With chemical and ice cleaning, personnel must enter the HRSG to perform the cleaning, increasing risk of injury. (To EPRI’s knowledge, there have been no reported injuries as a result of these methods.)

With respect to efficacy, tests at Pursley’s plant demonstrated that pressure wave cleaning can reach deeper into tube bundles and clean sections unreachable by other methods.

“Our units are near design level now,” says Pursley. “It’s like we just put in two brand new HRSGs.”

### The Work Ahead

A preliminary finding from these and other field tests since 2015: In the near term, it appears that pressure wave cleaning does not result in cracking or other adverse metallurgical impacts in tubes, liners, and other HRSG components. With the Colorado School of Mines and other partners, EPRI will follow the development of this technology and continue field testing to confirm that there are no such short-term effects. It will also examine potential long-term effects on component integrity and plant reliability.

Pressure wave cleaning must be done when the plant is offline, but that could change.

“There is potential for online cleaning in conventional boilers,” said Carson. “EPRI will be looking into that with Bang & Clean.”

EPRI also will examine pressure wave cleaning for air heater baskets, electrostatic precipitators, wires, and other boiler surfaces.

“It’s premature to say that pressure wave cleaning is superior to other methods,” said Carson. “EPRI is still researching the technology and its possibilities. But early results show that it could offer the industry new options.”

### Key EPRI Technical Experts

Bill Carson



Technology At Work

## Maximizing Reliability of Instrumentation and Controls

### *EPRI Collaborates with Chinese Nuclear Utility to Transfer Insights from Successful Reliability Program*

**By Scott Sowers**

An EPRI [report](#) documents an innovative program at China General Nuclear Power Corporation (CGN) that has significantly reduced the frequency of unplanned reactor shutdowns related to instrumentation and control (I&C) equipment failures. The product of a two-year collaboration between EPRI and CGN, the study offers insights and lessons to nuclear operators worldwide.

I&C equipment serves as a nuclear power plant's central nervous system, measuring and controlling various parameters for safe, reliable operations. While most printed circuit cards that reside in the equipment continue to work well, the nuclear industry has observed that more circuit cards are failing, leading to unscheduled shutdowns, lost revenue, and other operational problems for power producers.

"Failure rates have increased primarily due to component aging and improper storage and handling," said EPRI Technical Leader Stephen Lopez.

#### **A New Program to Reduce "Scrams"**

Beginning in the late 1990s, CGN plant workers noticed an increased frequency of unplanned shutdowns, or "scrams," attributable to failing circuit cards and I&C equipment.

"I&C reliability was the main contributor to scrams in our nuclear power plants," said Ma Shu, a chief engineer with CGN. "We discovered that these issues created 70% to 80% of our unplanned outages, many of which occurred at peak demand."

To reduce these scrams, CGN developed and implemented an I&C aging management program, with positive results: While there was an average of nearly six unscheduled shutdowns per year in the late 1990s as a result of I&C equipment failures, no such incidents were reported from 2003 to 2013.

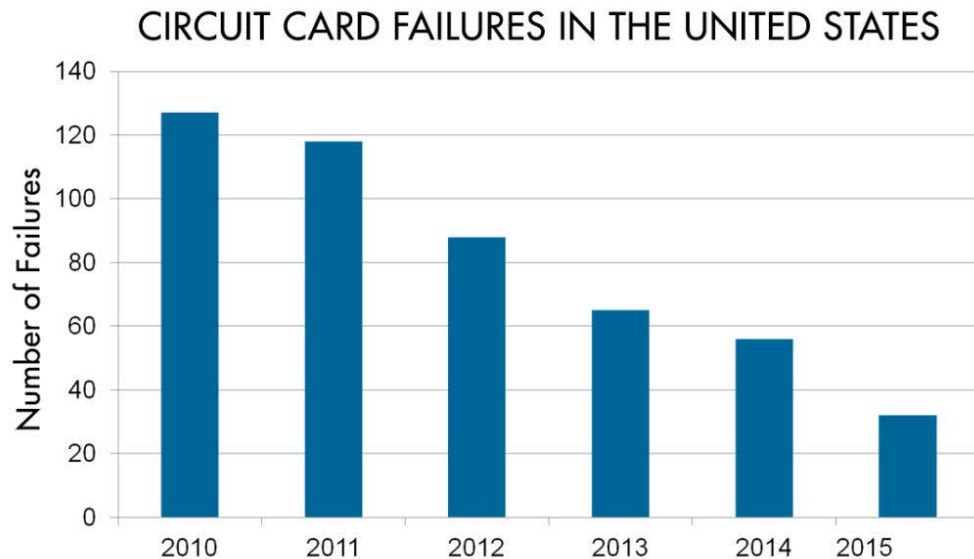
The program categorizes components based on how essential they are to reliable operations along with their aging characteristics, then tracks failure rates throughout the life of the equipment. Different strategies are assigned to each category and stage of equipment life to help prioritize testing, monitoring, and maintenance. CGN also developed technical standards and technologies to diagnose degradation and faults in circuit boards and other I&C components, including power supplies, fuses, and relays.

The program's other key aspects include:

- A database for tracking equipment status, test history, and operating experience
- Monitoring plant environmental conditions, such as temperature, humidity, and radiation
- Preventive maintenance and replacement of critical equipment with spare parts

After CGN joined the Instrumentation and Control Program in EPRI's Nuclear Sector in 2014, EPRI researchers made a series of visits to China to learn how the program reduced I&C-related reactor and turbine trips and to collaborate on technology transfer.

“The best way to reduce circuit card and circuit card–related I&C failures is to study reliability, develop a program that monitors components and mitigates failures, and then implement and track the program,” said Lopez. “CGN dedicated funding to long-term planning and resource development that supported new laboratory testing facilities and highly qualified staff to operate and manage them. Another strength is CGN’s use of metrics to benchmark the performance of its reliability program against other such programs.”



Source: Institute of Nuclear Power Operations

Since EPRI launched its Gold Card project, the number of circuit card failures has significantly decreased.

“It’s our honor to become a member of EPRI. We are delighted to see CGN working with EPRI on technical collaboration,” said Ma Shu.

EPRI has been examining I&C reliability and circuit card issues in nuclear plants for more than a decade. Published in 2010 and updated in 2011, [EPRI’s “Gold Card”](#) report provides information on degradation mechanisms and failure risks for I&C circuit cards, along with best practices to prevent failures.

The nuclear industry has used the Gold Card report and other guidance to improve circuit card reliability, as demonstrated by declining circuit card failures reported to the Institute of Nuclear Power Operations (see chart). CGN has used the EPRI guidance to enhance equipment storage, refurbishment, and processes to control electrostatic discharge. As another example, FirstEnergy has applied it to reduce “infant mortality” failure (occurring shortly after components are installed) and to improve its circuit card refurbishment process (see p. 34 in the [Winter 2014 issue](#) of *EPRI Journal*).

“Through the exchange of information and technology, EPRI continues to help address challenges facing the nuclear industry by bringing together its members and diverse scientific and technical communities,” said Lopez.

### Key EPRI Technical Experts

Stephen Lopez

## R&amp;D Quick Hits

## Gigawatt-Hour Savings in Store?

### *Study: LEDs Can Replace Fluorescent Lights with Equal Performance and High Efficiency*

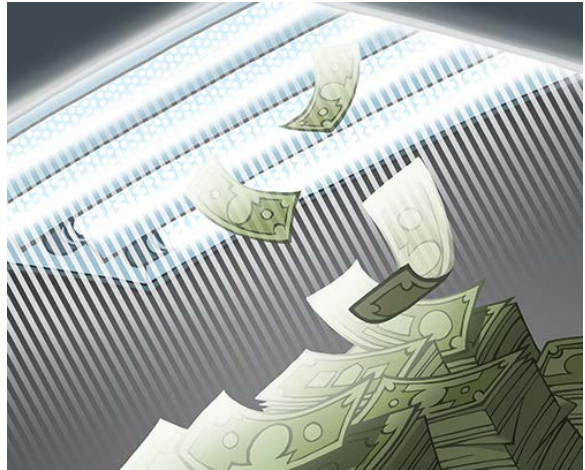
An EPRI [study](#) indicates that utilities should consider linear light-emitting diode (LED) lamps and troffers for rebates and incentives in their energy efficiency programs to replace linear fluorescent lights in the commercial sector. The switch offers significant energy savings with adequate light levels and payback.

Researchers scanned the LED market for potential fluorescent light replacements and examined 20 products in EPRI's lighting laboratory, measuring light output, efficacy, illuminance, energy savings, and payback. LED lamps offered energy savings of 25–61% relative to fluorescents. LEDs in dimmable troffers provided 28–36% savings at full output and 47–53% savings when dimmed to match the fluorescents' luminous flux.

Based on energy savings, LED lamp payback is 1–5 years, while payback for the more expensive troffers is 10–12 years. If LEDs last longer than fluorescents as manufacturers claim, reduced maintenance costs could shorten payback.

Because of varying LED product designs, the authors recommend that utilities vet products before providing rebates. They point to additional potential energy savings when dimmable LED troffers are combined with networked controls and demand response programs.

For decades, linear fluorescent lights have dominated U.S. commercial and industrial lighting. Replacing them with LED products offers the potential to save thousands of gigawatt-hours per year.



## R&amp;D Quick Hits

## Driving Cleaner Air in the Tennessee Valley

### *EPRI Study: Driving EVs and Off-Road Electric Equipment Could Improve Air Quality*

By 2030, deployment of electric vehicles and off-road electric equipment can lead to modest, but widespread, emissions reductions and air quality improvements in the service area of Tennessee Valley Authority (TVA), according to an EPRI [study](#).

Using an EPRI model and TVA market data, researchers projected that in 2030, electric vehicles would account for 9% of vehicle miles in the TVA region, and various types of electric off-road equipment would capture market share ranging from 17% to 85%. Based on this, they modeled the impacts on air quality and emissions. Main findings:

- Ozone decreases across the region, including reductions of up to 1 part per billion in urban areas. This is significant given the stringency of the National Ambient Air Quality Standards.
- Nitrogen oxide (NOx) emissions decrease by 3%, with 44% of the reduction coming from off-road electrification.
- Volatile organic compound emissions decrease by 5%, with 65% of the reduction coming from off-road electrification.
- Particulate matter emissions decrease by 1%, mainly in urban areas and along interstates in eastern Tennessee, with 79% of the reduction coming from off-road electrification.



Electrification more extensive than that modeled in the study could reduce emissions more significantly. The TVA results mirror those of a 2015 [EPRI-Natural Resources Defense Council](#) study that quantified nationwide air quality benefits from increased vehicle electrification.

## R&amp;D Quick Hits

## What Might the Electricity Mix Look Like in 2030?

### *EPRI Models 13 Scenarios to Examine Key Uncertainties*

Between 2015 and 2030, coal's share of the U.S. electric generation mix could decline significantly, while natural gas's share is likely to grow, according to a recent [EPRI study](#).

Using EPRI's U.S. Regional Economy, Greenhouse Gas, and Energy (US-REGEN) model, researchers examined 13 scenarios, including low and high natural gas prices, flat and increasing electric load, low-cost utility-scale solar photovoltaic technology, refurbishment costs for aging coal- and natural-gas-fired plants, potential paths to implement the federal Clean Power Plan, and other policies to reduce CO<sub>2</sub> emissions in the U.S. electric sector. Key insights:

- Between 2015 and 2030, coal's share of the U.S. generation mix could decline from 33% to less than 25% if natural gas prices remain low, new federal climate policies are enacted in addition to the Clean Power Plan, or aging coal units face significant refurbishment costs.
- New natural gas generation remains a significant part of the U.S. generation mix in most scenarios, including those with a stringent CO<sub>2</sub> emissions cap, and is expected to grow significantly in some scenarios. The main risks are high natural gas prices and targeted regulation to reduce dispatch or deployment of natural-gas-fired units.
- Relative to natural-gas-fired generation, renewable generation from utility-scale wind and solar power remains economically uncompetitive in most scenarios without CO<sub>2</sub> policies, even with a 17% reduction in capital costs for onshore wind between 2015 and 2030. This result is driven by the assumptions of low natural gas prices, expiring tax credits, and no further increases to state renewable portfolio standards.
- Existing and new nuclear generation are expected to be competitive in scenarios with significant CO<sub>2</sub> reduction requirements or high natural gas prices.



## R&amp;D Quick Hits

## Time to Plan for the Future Workforce

Knowledge related to nondestructive evaluation (NDE) in nuclear plants needs to be preserved and transferred to a new generation of workers, or it will be lost, an EPRI [study](#) concluded.

A 2016 survey of major NDE personnel providers for the nuclear industry found that:

- About half the workers are older than 45, and about 25% are older than 55.
- Since 2014, the size of the workforce has declined by 3% each year.
- Trainees and workers with entry-level certifications account for 6% of the workforce—not enough to fill the gap left by retiring workers with higher level certifications.



Over the next 10 to 20 years, half of the NDE personnel will potentially leave the workforce. To sustain safe, reliable operations of the nuclear fleet, the authors say that it is essential for industry stakeholders to collaborate on recruitment of new personnel for NDE careers.



## R&amp;D Quick Hits

## Go with the (Better) Flow?

### *Study: Highly Fluid Concrete Can Reduce Time and Labor of Nuclear Plant Construction*

Self-consolidating concrete offers potential to significantly reduce time and construction costs associated with placing concrete for nuclear power plants, according to an EPRI [study](#).

When conventional concrete is placed, technicians must temporarily liquefy it with vibrators so that it flows around obstacles and fills forms. This is particularly labor-intensive work in building nuclear plants' complex structures with reinforcing steel. Developed in Japan in the mid-1980s, self-consolidating concrete contains chemicals that promote fluidity and stability and has been used successfully in commercial and industrial buildings and nuclear plants in the United States and China.

When placed in one area of a concrete form, it flows throughout the form without the use of vibrators, potentially reducing time and labor.

Laboratory tests determined that it has slightly higher compressive strength relative to conventional concrete, given comparable water-cement proportions. Self-consolidating concrete exhibited slightly more shrinkage and slightly less splitting tensile strength. In test molds for power plant foundations and walls, self-consolidating concrete flowed freely through complex structures (see video).

As with conventional concrete, researchers found that careful selection and proportioning of ingredients can help avoid problems such as segregation. Different mixtures may be needed for different plant structures.



Photo of construction of Vogtle Unit 3 courtesy of Georgia Power.

# EPRI JOURNAL

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