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EPRI JOURNAL

ADDITION BY SUBTRACTION

Why carbon dioxide removal is key to achieving aggressive climate goals

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Addition by Subtraction

Why carbon dioxide removal is key to achieving aggressive climate goals

By Chris Warren

The release of the most recent United Nations Intergovernmental Panel on Climate Change (IPCC) report last August triggered an avalanche of alarming headlines. Many news outlets chose to highlight UN Secretary-General António Guterres' description of the report's findings as a "code red for humanity."

While this study explored potential future climate change, previous IPCC research outlined a range of possible emissions pathways to limit average global warming to well below 2°C above preindustrial levels, the long-term goal articulated by the 2015 Paris Climate Accords. Two common features shared by all the pathways are rapid emissions reduction and carbon dioxide removal from the atmosphere. Put simply, carbon dioxide removal (CDR) approaches, and technologies are likely essential.

"All analyzed pathways limiting warming to 1.5°C with no or limited overshoot use CDR to some extent to neutralize emissions from sources for which no mitigation measures have been identified and, in most cases, also to achieve net negative emissions to return global warming to 1.5°C following a peak," the report's authors wrote. "The longer the delay in reducing CO_2 emissions towards zero, the larger the likelihood of exceeding 1.5°C, and the heavier the implied reliance on net negative emissions after mid-century to return warming to 1.5°C."

EPRI has a long track record of research and modeling work to better understand a host of issues related to CDR, including the potential role and risks of individual approaches, their impact on warming, and the attainability of climate goals, as well as how CDR should be considered in utility planning decisions. Recent work has utilized EPRI's MERGE model, which combines a wide variety of scenarios that include global temperature goals, CDR options, policies, and energy system impacts, to better understand opportunities, risks, and uncertainties associated with carbon dioxide removal.

One of the findings to come out of EPRI's modeling work underscores the IPCC's findings regarding the importance of CDR. "Not only does it look like carbon removal technologies are valuable in pursuing goals limiting warming to below 2 degrees Celsius," said Steven Rose, a senior research economist, and technical executive at EPRI. "Our work shows that it is far more expensive and may be impossible to achieve these goals without CDR." In fact, many models, including EPRI's, are unable to produce solutions that limit warming to 1.5°C, or even 2°C, without CDR.

Even with highly successful decarbonization efforts across the economy, it will still be difficult and expensive to abate emissions from some sectors, including aviation, shipping, and certain heavy manufacturing processes. The ability to remove carbon from the atmosphere provides flexibility to transition more easily while new and cost-effective decarbonization approaches for those industries are developed.

Carbon Removal Approaches

Avenues that limit warming to below 1.5°C involve dramatic emissions reductions and likely removal of billions of tons of carbon dioxide each year by 2050. The most prominent CDR technologies include terrestrial strategies, bioenergy with carbon capture and storage (BECCS), and direct air capture (DAC).

Terrestrial strategies. Some of the most effective CDR strategies don't require advanced technology development. Instead, they involve expanding forestland and improving agriculture and soil management practices to tap the natural world's power to sequester more carbon. "The terrestrial strategies are available now. We can plant trees and restore deforested areas and change agricultural practices to store more carbon," said Rose.

A study published in the journal *Science* pinpointed tree planting as one of the most potent and economical ways to address climate change. In their analysis, the report's authors identified over 1.7 billion acres where trees would naturally grow without encroaching on existing cropland. The result would be the removal of two-thirds of all emissions related to human activities.

Besides being immediately available, tapping the capacity of trees to store carbon through photosynthesis also has the benefit of being relatively cheap, typically costing less than $50 per metric ton of carbon. Healthy forests also improve air and water quality, and storing carbon in soil can improve crop yields. There are, however, tradeoffs to be considered, particularly in how land-use choices impact other societal priorities. For example, afforestation could reduce the amount of farmland available to grow food.

Bioenergy with carbon capture and storage. Some of the same dynamics that make terrestrial strategies effective at removing carbon from the atmosphere are also at play with BECCS. Just as forests can sequester carbon via photosynthesis, BECCS can capture planet-warming emissions using plants, trees, and waste streams.

However, BECCS is a more complex process that involves producing energy with biomass while also capturing emissions before they can make it into the atmosphere. Those emissions are then stored underground or are used in products such as fuels, chemicals, and concrete. Calculating the carbon impact of BECCS is not easy. That's because there are many uncertainties about the cost and performance of energy technologies, the supply of bioenergy feedstocks, and logistics. Little is known about these and other factors because there is scant experience with BECCS facilities. Other considerations also need to be weighed, including the effectiveness of the carbon capture technologies and, as with afforestation, replacement of agricultural land with crops grown for BECCS.

As is true of terrestrial CDR approaches, the potential of BECCS is heavily influenced by the policies used to incentivize and implement it. Besides producing power, BECCS can be used to produce hydrogen and liquid biofuels. In all cases, though, BECCS can involve land-use choices that could impact food production, greenhouse gas emissions, and other societal priorities. However, these environmental and social implications vary depending on the type of biomass used. Some biomass can be produced in a way that doesn't involve much land displacement and leads to a net reduction in emissions; other sources of biomass require a significant amount of land and result in additional emissions. Ongoing research by EPRI is examining and quantifying these impacts.

Direct air capture. Like those for BECCS, technologies to directly remove carbon from the atmosphere are nascent. DAC utilizes a chemical process to remove carbon dioxide and relies on underground infrastructure to store it. "It basically catches the carbon out of the atmosphere, and once you've caught it, it goes into a pipeline where you can then inject it into the ground," said Rose. "It takes those molecules and redirects them below ground for storage purposes or potential utilization."

A great deal of research is being devoted to DAC today. While early research results indicate that DAC is technically feasible, the larger question about its viability revolves around economics. "There's still a lot that needs to be understood in terms of the energy use of that technology. It's very energy intensive, and if you are trying to modify your energy system for decarbonization, how do you ensure that you're doing it in a compatible way?" said Rose.

Impact on Utility Planning and Investments

The findings of the CDR research and modeling work EPRI has done underscore the importance of removing carbon from the atmosphere as a way to achieve ambitious climate goals. If global emissions continue to rise, the importance of CDR will also increase.

"It’s more expensive to pursue the goals if you wait. And it is also potentially not just more expensive but impossible to get there,” said Rose. “If current upward trends in global emissions continue, it becomes more difficult to achieve the ambitious international goal, and CDR becomes even more important to the viability of that goal.”

One objective of EPRI’s work has been to evaluate how CDR may impact utility investment and planning decisions. For example, EPRI’s modeling work has examined how DAC and BECCS could affect utility revenues. “Those two CDR options represent revenue opportunities for the electric sector,” said Rose. “You can imagine a biopower with CCS plant being used to provide energy for a utility’s customers and receiving payments for carbon dioxide removal services.”

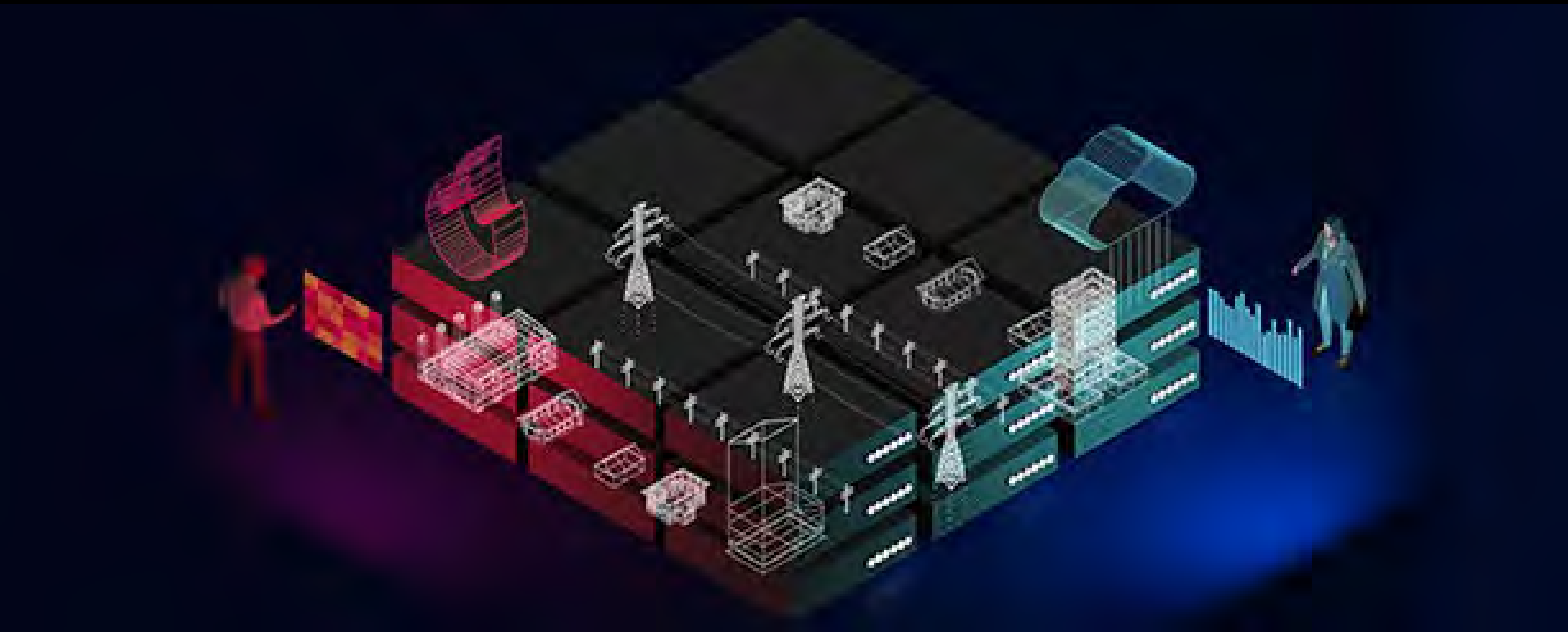
Because DAC is energy-intensive, it can also potentially increase electricity demand. Therefore, it represents an opportunity to harness surplus renewable generation and always-on nuclear power.

CDR could also impact planning if it allows a utility to continue operating a power plant that emits carbon dioxide during the transition to a low-carbon energy system. Continuing to operate such a plant could lower the overall cost of transitioning to a net-zero carbon energy system and provide a utility with more flexibility to move towards non-emitting generation.

Finally, understanding the potential role of CDR is important to fully grasp future utility risks and uncertainties. “It represents a potential revenue stream, but it also represents an uncertainty,” said Rose. “In addition to other uncertainties about load growth, fuel markets, low-carbon technology, and policy, it’s another uncertainty companies would want to evaluate as a potential decarbonization risk.”

EPRI Technical Expert

Steve Rose



Navigating Complexity

An EPRI Incubatenergy project highlights the benefits of simulations in improving grid resilience in the face of complex disasters.

By Chris Warren

One of the most important lessons Gary Rector learned during his time as a wilderness guide was that accidents are rarely the result of just one factor. "We focused on multiple events," said Rector, a data scientist with the Arizona utility Salt River Project (SRP). "If there is an accident in the wilderness, it is almost always due to multiple causes, like human error, the environment, and equipment failure. It's the combination of two or more things that causes the problem."

That insight was one reason Rector was eager for SRP to participate in one of EPRI's Incubatenergy Labs 2020 pilot projects. The project brought together EPRI, SRP, and Edmonton, Canada-based technology company RUNWITHIT Synthetics (RWI), which combines artificial intelligence (AI) and machine learning with large and diverse sets of data to simulate complex events. For instance, in the past, RWI simulated an earthquake in Santa Clara, California, and demonstrated how sensors could be used to detect gas and water leaks, identify if a utility pole was down, and facilitate accurate disaster communication with citizens.

In this project, RWI was tasked with modeling the potential impacts of a 7-hour power outage during a pandemic on a 15.6-square-mile district in SRP's Phoenix and Tempe, Arizona, service territory. The goal was to simulate the impacts of these two simultaneous disasters on the 18,249 homes and 2,000-plus businesses in the area. SRP sought a better understanding of how simulations can improve utility decision-making and planning to prepare for and respond to disasters and improve overall grid resilience and outage management.

"We plan for outages, and we understand a bit about predicting outages due to asset failures, which usually happen with transformers and distribution lines," said Rector. Like wilderness accidents, the complexity of outage response and grid resilience flows from the multitude of forces—everything from weather conditions and their impact on grid infrastructure to people's decisions and priorities—that intermingle and evolve during an event.

The scenario examined in Phoenix underscores just how complex these dual disasters can be. Phoenix in July is scorching hot, with an average high temperature of above 106˚F, according to the National Weather Service. While such a high temperature alone can cause grid equipment failures, Phoenix can also flood during the summer when short bursts of torrential rainfall hit ground so baked by the heat that it cannot absorb the water. In fact, Phoenix set a record for most rainfall during a single July day this year, when 0.8 inches fell on July 23.

The experience of COVID-19 has shown that a pandemic alters lifestyles and work patterns, changing energy consumption habits and adding even more complexity to the situation. "There were lots more people at home and very different load curves for certain neighborhoods, and that can affect transformer health," said Rector. "We had difficulty putting our arms around that. We want a predictive model that says, 'Replace these transformers before they fail' or 'These distribution or transmission lines are likely to fall in the next big storm.' Some of that we can do, but to pull all of these multiple events together as a data scientist and allow for predictive modeling is extraordinarily difficult."

Using Synthetics to Model Reality

RWI was one of just ten startups chosen from more than 130 applications to participate in the 2020 EPRI Incubatenergy Labs Challenge. The challenge provides opportunities for startups to demonstrate innovative technologies that can benefit everything from grid resilience and reliability to energy management and decarbonization. Other startups selected in 2020 included Kognitiv Spark, which developed an augmented reality tool to digitally connect utility workers with subject matter experts to teach them new skills and help troubleshoot problems, and Sharc Energy Systems, which provides wastewater heat recovery systems for multifamily buildings.

EPRI and a group of utility advisors from SRP, American Electric Power, Ameren, and Xcel Energy provided RWI with weekly guidance and industry expertise throughout the 10-week project. "We sought to establish parameters for RWI's modeling," said Omar Siddiqui, an EPRI senior program manager who worked on the SRP project. "Since RWI had no prior utility experience, we advised them on what types of data would be key for their analysis."

Initially, SRP planned to provide information about customer load curves, the location of grid infrastructure, and municipal emergency response services within the specified modeling district. However, the project's aggressive schedule did not allow sufficient time to go through the necessary protocols that safeguard certain types of utility and customer data.

That wasn't a problem for RWI, though, because the company is an expert in simulating complex events through the use of synthetics. "Synthetics are AI-based entities that react, respond, learn, and are context-aware," said Myrna Bittner, CEO, and co-founder of RWI. "They can be models of people, businesses, consumption, devices, controls, weather, all types of infrastructure or events."

RWI had to quickly collect large amounts of publicly available data to create highly accurate and localized synthetics. "RWI used Google Earth and public documents to construct a representation of the utility infrastructure and other critical infrastructure in the area," said Siddiqui. To better understand load curves during the pandemic, RWI used data from a study by the Smart Energy Consumer Collaborative, which tracks consumption trends and projects future consumer energy investments in technologies like solar photovoltaics and electric vehicles based on customer demographics.

To help understand the residents and businesses in the area, RWI assembled census, property, and taxation data from Maricopa County and health information from the Arizona Department of Health Services. "We also dove into data and sales reports of generator companies to see which houses and businesses would be likely to have backup generators as well as the type of fuel and size of the generation capacity," said Bittner.

In total, RWI assembled and connected over 200 models to create a synthetic representation of this particular district in SRP's service territory and then validated aspects of it with SRP and EPRI. "The load curves they came up with matched almost identically the ones our dispatchers used," said Rector.

However, what was unique was how RWI could model human behavior and decisions during an outage based on health, socioeconomic, demographic, and other data. This allowed RWI to simulate the decisions homeowners and businesses would make at different times throughout an outage and also track their attitudes towards the utility and their willingness to pay for improved resilience in the future.

These individual decisions have cascading impacts. For instance, a business or homeowner with a backup diesel generator will contribute to a spike in greenhouse gas emissions during the outage but will not need to be prioritized in a utility's grid repair efforts. Utility decisions and communication efforts can also impact customers' decisions and attitudes. This simulation provides utilities with insights into how individual households and businesses will respond to actions taken by a utility during a dual-disaster event.

"The synthesized population is an active system during an outage," said Bittner. "Some people are at home trying to work; some have health conditions to consider and rely on oxygen. All of these households are impacted by stress in different ways during an outage. When we turned the lights out and moments ticked by, we could see the key decision points and stress levels. Those were especially high when someone in a house had COVID or was relying on oxygen that was disrupted because of the outage."

The Value of Simulation for the Entire Industry

The fact that RWI was able to put together an accurate synthetic environment without using utility data or collecting information using sensors and other equipment is important. It means that simulations that can guide utility decisions and investments related to grid resilience don't have to risk data breaches or require long-drawn-out regulatory approvals.

This proof-of-concept project will help Rector make a case for the use of simulations to make better decisions. "The value is showing to management that a simulation is extremely useful," Rector said. "Such a simulation engine would let us anticipate grid resiliency problems and let us anticipate staffing and financial problems across the business. All these areas are addressed with the same simulation technology because all of the pieces are interconnected."

For the industry as a whole, RWI's inclusion of the human component in resilience planning may very well be the most important lesson of this project. For example, RWI produced a heat map during the simulation that identified the most vulnerable populations—particularly those whose health could be most negatively impacted by an outage—which the utility could use to make decisions about which repairs to prioritize.

Sara Mullen-Trento, strategic issues lead at EPRI who also worked on the project, believes that a modeling and simulation approach that acknowledges the role of human behavior and attitudes is an especially valuable tool for resilience planning.

"There are so many questions when it comes to improving resilience that people don't know where to start," said Mullen-Trento. "This is a great way to test out research questions around how customers will respond to utility programs or whether they're likely to adopt technology on their own. The ability to integrate not only models but also visualize that complex environment is eye-opening; it underlines the many things we need to think about as we plan for the future and the need to approach planning as holistically as possible."

EPRI will continue to explore how synthetic simulations can support decision making for grid resilience. EPRI plans to continue working with RWI, member utilities, and other stakeholders to advance synthetic simulation as a decision support tool for a range of utility use cases.

"There are so many open questions when it comes to improving resilience planning that it's hard to know where to start," said Mullen-Trento. "This approach helps us answer a lot of questions and opens new avenues to see how different events and decisions play out. We want to do a lot more of that."

EPRI Technical Experts

Omar Siddiqui, Sara Mullen-Trento

Battling Wildfires

EPRI's research aims to improve prevention of and response to wildfires and other extreme weather events

By Chris Warren

The California Department of Forestry and Fire Protection (CAL FIRE) is a clearinghouse of information about wildfire events and trends in the state. In recent years, summaries of wildfire seasons have been similar to this description of 2020: "The 2020 California wildfire season was characterized by a record-setting year of wildfires that burned across the state of California as measured during the modern era of wildfire management and record keeping," the department wrote.

Indeed, 2017, 2018, and 2020 were all record-setting wildfire seasons, as measured by acres burned, number of fires, structures damaged or destroyed, and lives lost. Wildfires are by no means a problem faced only by California. According to the National Interagency Fire Center, over 46,000 fires burned more than 7.5 million acres across the United States in 2020.

Wildfires are a significant challenge in a growing number of states across the country, particularly as climate change leads to warmer temperatures and longer droughts. For utilities, the challenge posed by wildfires is both large and complex.

"There is clearly an urgency on the part of utilities to understand and to implement approaches that reduce wildfire risks. These implementations are complex because sometimes they relate specifically to utility ignition incidents and other times they are associated with damage and other impacts to the power infrastructure," said Doug Dorr, an EPRI technical executive who is leading research to help utilities prepare for and respond to wildfires and other extreme weather events. "The number one utility objective is public and worker safety. When you think about that, it means that the first thing you do is implement designs and technologies that minimize the risks of ignitions happening in the first place."

EPRI has a long history of research into technologies and techniques to improve grid resilience against extreme weather. In fact, EPRI was founded in the wake of a weather-related blackout that hit the northeastern United States and Ontario, Canada, in 1965.

Preventing wildfires from starting is a focus of EPRI's research, testing, and pilot and demonstration projects with member utilities. EPRI's work involves mechanical, electrical, and lifecycle performance testing. Preventing grid infrastructure from igniting fires—and avoiding customer outages caused by wildfires—are big priorities for utilities. But it's important to remember that utilities alone can't prevent wildfires, which is why improving wildfire response is also so critical. "Even if utilities were perfect at preventing ignition events that start fires, it would impact the number of fire starts by less than 10 percent," said Dorr. "Not that many fires are started by power systems."

Indoor and Outdoor Lab Testing

In June 2019, EPRI launched a three-year grid safety and resilience initiative aimed at helping utilities to plan, design, and operate their power systems in the face of extreme weather and wildfire events. The initiative involves a mix of equipment testing at EPRI's facility in Lenox, Massachusetts, and field demonstrations with member utilities. The ultimate goals of the work are to help utilities design their grids to be as resilient as possible; to test equipment able to withstand extreme weather; to optimize utility response to and recovery from natural disasters; and, whenever possible, to avoid or reduce the impacts of weather-related outages.

Maximizing grid resilience against wildfires and other extreme weather events requires using equipment that can withstand years of exposure to harsh weather. At EPRI's Lenox laboratory, grid equipment such as covered conductors, connectors, and insulators are placed in a customized environmental chamber. Equipped with ultraviolet lights, high-voltage electricity, and the ability to expose assets to salt fog, the aging chamber accelerates the normal aging process of equipment threefold, meaning three years in the chamber is like a decade under normal conditions.

The facility also includes an outdoor test yard, where equipment is exposed to extreme electrical and physical stresses. For example, researchers utilize Mylar balloons and vegetation to replicate the arcs and sparks that can ignite wildfires. The aim of these tests is to better understand the lifecycle performance of different products and to compare the resilience of similar products made by different manufacturers.

EPRI works directly with member utilities to test these products and to vet new grid equipment a utility is considering using. Improved knowledge about how conductors, insulators, and other equipment function under extreme weather conditions helps utilities guide important investment decisions. "Ideally the equipment needs to last the life of the system, which in some cases might be 40 or 50 years," said Dorr. "You can't go back in 10 years and spend $2 billion to redo it because you didn't get it right the first time."

Another component of the research is to evaluate designs of distribution and transmission grids for resilience. One way to help prevent wildfires is to design transmission and distribution poles to ensure they remain intact so that the lines stay in the air. "Generally, a resilient design takes the half dozen force-bearing components and goes through each one to make sure the weak link is not the pole," said Dorr. "You can create a design where the force goes to components you want to break and not to the ones you know are time consuming and costly to repair if they do break."

Helping to Develop and Test New Technologies

As the task of preventing and responding to extreme weather events becomes more challenging, utilities are exploring ways technology can improve grid resilience. EPRI assists in that effort by helping to evaluate new technologies. "EPRI's primary role in this space is to look at the emerging technologies and to use our network of experts to do the initial vetting to see if there is an opportunity to try it out in the extreme weather or wildfire space," said Dorr. Technologies that prove to have potential can then be tested in the field with the help of member utilities.

There is a meaningful pipeline of technologies that either are already available to utilities or show promise. For example, as part of EPRI's Incubatenergy program, which works with startups whose products and services could benefit the utility industry, Dorr is collaborating with San Francisco-based Pano AI. The company has developed high-definition, 360° cameras that can be installed on transmission towers and other elevated observation points. Historically, cameras used to monitor utility grid infrastructure have only provided a view in one direction and didn't have the benefit of algorithms to evaluate images and trigger alerts at the first sign of fire.

"These new cameras run AI algorithms that can filter out fog and clouds and other false positives and pick out smoke in near real time as a fire starts," said Dorr. "Utilities can overlay the platform Pano AI has created over their system and they know if smoke is from their system, how close it is to transmission lines, and whether to shut the lines down if the fire gets too close. The camera is the tool and the AI is the enabler that allows you to react fast to provide first responders with a greater chance of keeping the fire from spreading."

Technology can also help improve the accuracy and efficiency of the transmission and distribution line inspections that help identify trees and vegetation at risk of falling and igniting a fire. One EPRI project is investigating how satellite imagery can be used to identify vegetation that should be trimmed or dead trees and dry leaves that provide the fuel that can accelerate a wildfire. "We can use satellite imagery to look at the chlorophyll levels of pine trees or leaves of trees, and by looking at that spectrum you can see if they are healthy or dying and whether they are a risk or not," said Dorr. "That can be more cost efficient than walking the lines and can help to identify at-risk vegetation just beyond the rights of way, where inspections don't go."

EPRI also works with utilities to evaluate flame-retardant materials that can help protect utility poles. For example, an increasing number of utilities are wrapping wooden poles with an intumescent covering that will burn when exposed to flames but keep the actual pole safe from damage. EPRI's role is to be an independent third-party validator of manufacturer claims and to improve understanding of how these materials perform after aging and under environmental stresses.

SDG&E's Approach to Wildfires

Because of the increasing frequency and intensity of wildfires, California utilities are especially proactive about deploying advanced technologies and products to prevent and respond to the threat. San Diego Gas & Electric (SDG&E), for example, has implemented or is in the process of incorporating a wide range of new technologies and approaches to address wildfires.

For example, a wildfire can be caused if an energized power line is severed and hits dry vegetation on the ground. SDG&E uses technologies that determine when a conductor has broken and instantly cut the power before the line reaches the ground.

SDG&E has also become the first utility in the country to build its own weather network. The network provides the utility with updated weather data every 30 seconds, and SDG&E has augmented it with cameras able to measure the chlorophyll in vegetation and sensors that assess the moisture levels in brush. In addition, SDG&E is using satellites to monitor wildfire activity and is increasing its use of drones to evaluate grid infrastructure in areas facing high fire risks.

Not all of SDG&E's fire prevention methods are high tech. The utility is also relying on goats to eat grass near power lines, thereby removing fuel that can burn in a wildfire.

When this current phase of research is completed next year, EPRI will work with other utilities to help share findings and lessons learned. But Dorr doesn't expect research to help utilities navigate wildfires and other extreme weather events to end anytime soon. "I don't see this going away, and we will address this for the long term, just like we have been addressing hurricanes and ice storms," said Dorr. "We will continue this kind of research as long as we have challenges with resilience on the grid."

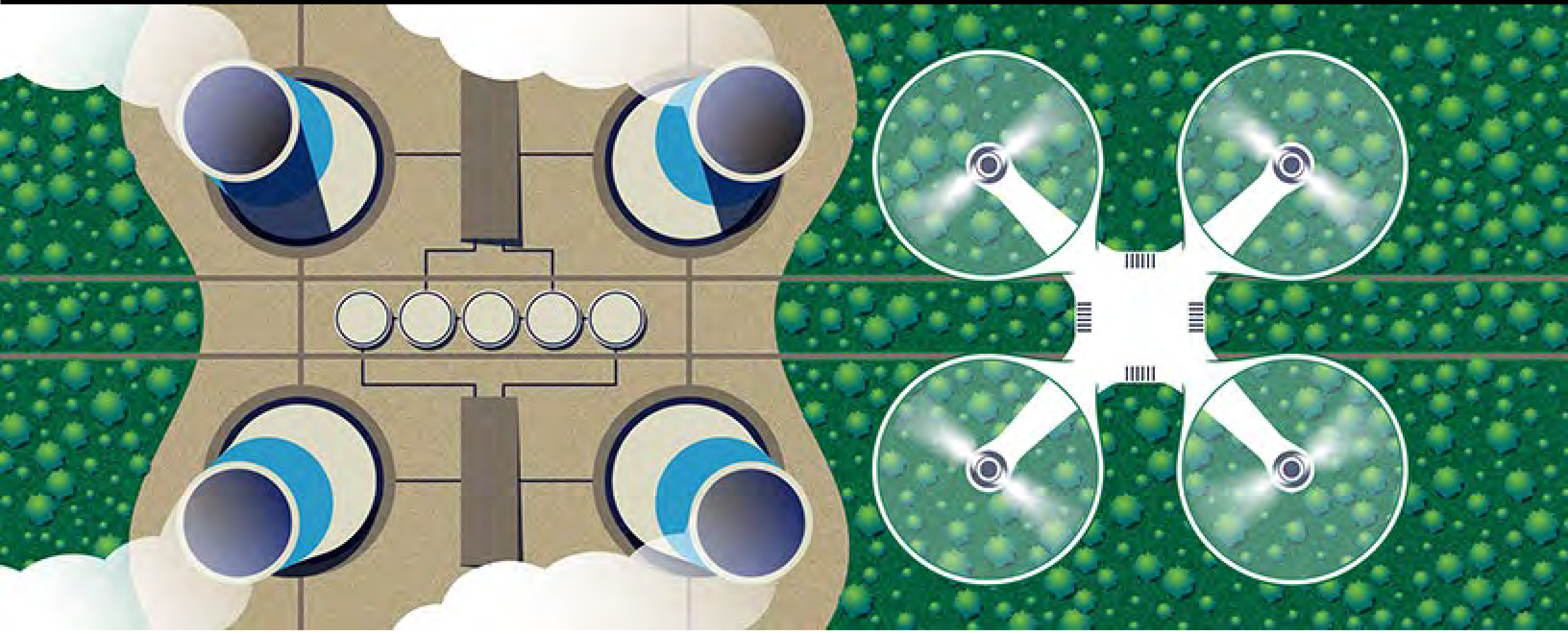
Resilience and Awareness

The scope of wildfire-related activities currently taking place is wide and is strongly influenced by the unique conditions each utility faces. "What it comes down to for utilities is continuous improvement in risk reduction and resilient design," said Dorr.

Because of that, EPRI's research in the transmission and distribution space largely falls into two broad categories. "The first is resilient infrastructure and right of ways, which covers everything we can do to reduce the risk of ignitions and of system impacts from wildfires," said Dorr. The second is geared towards accelerating awareness. "That covers leveraging of everything from weather and smoke to power flow sensors to help predict what might happen before it actually does," said Dorr.

EPRI Technical Expert

Doug Dorr



Data-Driven Decisions Benefit the Nuclear Power Industry

EPRI research investigates how artificial intelligence and data science can improve plant performance and lower costs

By Chris Warren

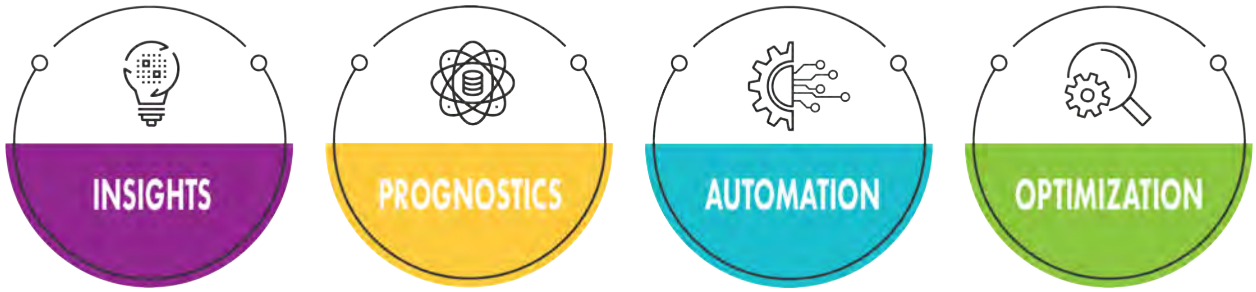
Containment buildings are critical for nuclear power plants' safe and reliable operation. Usually made of steel-reinforced concrete, these airtight buildings house everything from the nuclear reactor and its pressurizer to its cooling pumps, steam generator, and piping. The fundamental job of containment buildings is to prevent any radioactive materials from leaking into the atmosphere.

Regular and rigorous inspections of containment buildings are standard at nuclear power plants and are monitored by nuclear regulators. Traditionally, these inspections are a time-consuming, manual task involving plant personnel visually examining a containment building for potential defects, often from a large crane.

Recently, EPRI began investigating the possibility of replacing or augmenting the standard visual inspection of containment buildings with a combination of unmanned aerial systems (drones) and artificial intelligence (AI)-powered machine vision models. In simple terms, the idea is this: Use drones to collect an abundance of videos and still images of the containment building, then tap the power of AI to analyze those images to look for potential cracks, abrasions, corrosion, and other structural defects.

More specifically, in its initial research to pilot this new inspection technique, EPRI teamed up with a member utility to gather about 2,500 images of a containment building. Those images were then used to develop and train a model to pinpoint possible damage. This approach is still under development as part of a larger EPRI program called Data-Driven Decision Making (3DM), an effort to expand the use of AI and the value it can deliver to the nuclear power industry.

"3DM is providing tools and identifying problems AI might help with. These could include flexible power and other applications in nuclear plants, like operations maintenance and inspections," said Robert Austin, an EPRI senior program manager who leads a range of initiatives focused on plant modernization.



Four Research Areas

The 3DM program encompasses a multitude of individual projects. They can be bucketed into four broad categories:

- **Insights—**Artificial intelligence, machine learning, and data science have the capacity to improve the performance and operations of nuclear power plants in multiple ways. One way is by combing through data collected through years of past operations to look for insights, lessons, and best practices. For example, EPRI collected a large number of maintenance work orders from nuclear power plants and analyzed the data using AI algorithms. "It would be hard for one person to look through all of that data and figure out trends," said Thiago Seuaciuc-Osório, an EPRI senior technical leader who is supporting the 3DM initiative. "What AI allows us to do is to look at the entire body of data together and draw out insights and trends that a subject matter expert can then look at for guidance in their own decision making." EPRI is also developing a unique power industry dictionary to guide the text analysis done by AI. Without this fundamental natural language processing work, it would be extremely difficult or impossible to gather valuable insights from past work orders or equipment manuals.

- **Prognostics—**Ultimately, using AI to examine the past is a way to improve future decisions and operations. But data science technologies also make it possible to evaluate real-time plant data to predict important events, including equipment failure and the end of an asset's remaining useful life. Leveraging data and AI to predict future equipment failure gives nuclear power plant operators the information they need to prevent unexpected outages and strategically plan their inspections and maintenance downtime. To help turn data into useful insights, EPRI has launched an effort to make better use of all of the information that is currently being collected by sensors installed at nuclear power plants. EPRI is also applying machine learning techniques to improve flow-accelerated corrosion inspection programs. The ability to better predict failures could reduce unnecessary and costly inspections.

- **Automation—**The use of drones and machine vision models to inspect containment buildings is just one example of how AI can improve inspections at nuclear power plants. EPRI has several other projects to bolster automated nondestructive evaluation (NDE) tasks, including fuel assembly defect detection inside reactors and dry cask storage vents. If successful, these and other more automated inspection techniques could replace or supplement the costly and time-consuming work currently done by plant personnel. Leveraging automation is also an opportunity to eliminate otherwise inevitable errors. "Some activities performed by people are subject to human error," said Seuaciuc-Osório. "A good example is inspecting images of pipe looking for cracks. Most of the data they look at will have nothing because defects are rare. But after seeing hundreds of images with no defects, they may miss something because they're tired. That is where automation comes in for reliability, and there are lots of applications where data screened by automation highlights areas where inspectors should look closer."

- **Optimization—**EPRI is also exploring ways that AI can improve processes, plans, and strategies at nuclear power plants. One example is supply chain efficiency. Nuclear power plants prepare for a wide range of contingencies, which means that they order and warehouse a very large amount of inventory, much of which is never used. This is problematic because it can be expensive to store large numbers of unused items. AI can evaluate past order history and whether or not inventory was used to help guide future purchases. "We can look back and see how many times we purchased a part and never used it. AI comes in and takes all the information together and helps make decisions about what you should buy and what you don't need to stock," said Seuaciuc-Osório. "There is also a risk associated with not having a component you need on hand. AI can give you information about the likelihood you will need it, and you can decide what your risk tolerance is for not having it." Beyond driving supply chain efficiencies, EPRI is also investigating how AI can improve waste packaging, scheduling, and the costs of decommissioning activities.

How Artificial Intelligence Can Help Nuclear Plants Drive Decarbonization

While the U.S. nuclear fleet has a long track record of safe and efficient operations, AI provides a tool for improving its overall performance at a time when market pressures threaten the financial viability of some plants.

In particular, the influx of intermittent generation like solar and wind, along with low natural gas prices and flat electrical load growth, has contributed to changes in how nuclear power plants operate—changes that often have a negative impact on revenues.

Ensuring the continuing financial viability of America's nuclear power plants can play an important role in achieving ambitious decarbonization goals, including the Biden administration's target of a carbon-free electric grid by 2035. In fact, according to the U.S. Department of Energy (DOE), nuclear energy provided over 50% of the nation's carbon-free electricity in 2020.

"Artificial intelligence solutions can help to reduce costs to keep plants financially competitive. When plants remain financially viable, it indirectly helps with decarbonization efforts," said Seuaciuc-Osório.

EPRI's Role as Data Collector

Several significant developments have made it possible to tap AI to benefit the nuclear power industry. One is the proliferation of low-cost sensors able to monitor the operations and performance of the equipment in power plants. "Digitization means that it's no longer only about going out and looking at analog gauges," said Austin. "With digital sensors, you can constantly measure vibration noise and electrical current and bring that information back to a central location, where you can look at trend lines and see if something is wrong."

The capacity to deploy AI to analyze all of the data collected by sensors is possible today, thanks to dramatic drops in computing power and data storage costs.

But there are two fundamental truths about AI's capacity to deliver insights and other benefits to the nuclear power industry. One is that AI is only as good as the data that informs it; the other is that more data translates into better AI.

Data is very sensitive in the utility industry, especially among nuclear power plant operators. This is why EPRI is both promoting collaboration and data sharing while also developing safeguards for protecting data. "We developed a data intake process that is more formal and efficient than what was in place in the past," said Austin. "EPRI has worked to provide a process where we do this data intake with an infrastructure in place that includes governance processes that allow us to be good stewards of the data."

EPRI's future work will continue to explore ways to leverage the unique capabilities of AI to benefit the operations and performance of nuclear power plants. "AI is going to be an important part of how plants move ahead and become more efficient and valuable," said Austin. "Our work will continue to push and facilitate the collaboration needed to achieve that potential."

EPRI Technical Experts

Robert Austin, Thiago Seuaciuc-Osório

EPRI JOURNAL

EPRI's Advanced Nuclear Research Helps Develop Promising and Cost-Effective Zero-Carbon Technologies

Years in the making, advanced nuclear reactors can play a pivotal role in meeting climate goals

By Chris Warren

In October of 2020, the U.S. Department of Energy (DOE) announced $160 million in funding to support the construction of two advanced nuclear reactors. The funding announcement came just five months after DOE launched the Advanced Reactor Demonstration Program, which aims to provide $3.2 billion in funding over seven years to build cutting-edge reactors that have been in development for years.

The two reactor projects receiving DOE funding – funding that will be matched by private industry – are good examples of technologies that have the potential to make carbon-free nuclear power far more cost-effective than it has been in the past.

For example, the Natrium reactor being constructed by TerraPower on the site of a retiring coal plant in Wyoming is a high-temperature, sodium-cooled reactor that includes storage, which will allow it to operate flexibly to better support intermittent renewables like wind and solar. Another high-temperature reactor will be built in Washington State by X-energy. The X-energy plant will also be able to operate flexibly and will include a facility to produce TRistructural ISOtropic particle fuel (TRISO), which is designed to withstand extremely high temperatures.

Advanced Technology and Decarbonization Align

This flurry of activity is particularly important because the DOE funding requires that the reactors be completed and operational within seven years—an aggressive timeline, particularly considering that the typical development and construction timeline is about 10 years.

To Craig Stover, who manages EPRI's Advanced Nuclear Technology (ANT) program, the DOE's demonstration projects are an indication of just how much utility and societal attitudes towards nuclear power have changed over the past half-decade or so. "There was a time when the phone didn't ring a lot, and nobody thought of building a nuclear power plant," said Stover. "In the last two years, the phone has been ringing every day with people asking what they need to know to start building an advanced nuclear plant."

Two primary factors can explain this burst of interest in advanced nuclear technology. One is the increasing priority of utility decarbonization. At the end of 2020, for example, 70% of the largest U.S. utilities had set targets for net-zero emissions or deep decarbonization. "We hear from utilities that say they have committed to an ambitious carbon goal and run their models and realize they can't meet their targets without a nuclear plant," said Stover.

At the same time, though, there is a recognition that traditional light water reactors are too expensive to build. This is why the past decade and a half of research into advanced nuclear reactor technology is so consequential today. "When people developed advanced reactor technologies over the last decade, nobody knew that when we got to the early 2020s, utilities would commit to these net-zero and decarbonization goals," said Stover. "Now the technology is ready, and carbon goals are here, so these two things that have been happening in parallel have now connected."

Why Faster is Cheaper

The question for EPRI's Advanced Nuclear Technology program is how to conduct research that overcomes the challenges standing in the way of more accelerated deployment of advanced reactors. Ultimately, what that means is figuring out ways for nuclear plants to be built faster and cheaper – which, given that nuclear plant construction costs can be as high as $1 million per day, are intertwined obstacles.

At EPRI, the challenge of accelerating and lowering the cost of plant construction translates into multiple research initiatives. These projects all acknowledge that the timeline for getting an advanced nuclear reactor built and producing carbon-free electricity is about nine years. Therefore, if a utility wants to have a reactor up and running by 2035, it will need to complete site selection by 2026, have permit applications finished by 2029, and break ground in 2031 to accommodate the four-year construction time.

Given that timeline, one strain of EPRI's ANT work is to inform utility resource planning. "A lot of folks in the corporate offices of utilities are talking about what they need to know to build a plant in the next 10 to 15 years," said Stover. "We are developing training for them, and we have a siting guide and owner-operator requirements they can use early in the project to inform resource planning. This is an important area of research today because you have many utilities thinking about building a nuclear plant, and they have only two people working on it, and they need help."

Not surprisingly, Stover says the majority of questions he receives are about EPRI's multiple research projects devoted to slashing deployment costs. Many people, however, don't understand that the majority of expense for building a nuclear plant is not related to the area of the plant where atoms are split to generate electricity. "Everyone wants to talk about the nuclear plant, but what drives the cost is the fundamental construction activities like concrete and rebar," said Stover.

This is why EPRI projects have focused on improving the concrete and rebar that go into resilient power plants. For example, EPRI is researching ways to improve concrete mixtures and optimize the design of concrete reinforced structures. Because advanced reactor technologies operate at higher temperatures than traditional light water reactors, EPRI is also investigating whether extended exposure to elevated temperatures reduces concrete's durability.

Other EPRI research initiatives explore how advances in construction materials can accelerate their deployment. For instance, steel is a foundational material for most buildings. EPRI is examining how steel-plate composite walls that are made in factories can be used with advanced reactors. EPRI is also conducting research into self-consolidating concrete, which can flow into place without the help of labor. "When you talk about robust concrete structures and realize on-site construction costs are $1 million per day if you can pour concrete faster, it pays for itself fast. That is construction optimization," said Stover.

Faster and Cheaper Manufacturing of Components

EPRI has also spent years developing advanced approaches that speed the manufacturing of plant components and lower their costs. For example, today, it can take three or four years to manufacture a plant's reactor pressure vessel, and only a handful of companies worldwide can even do it. Since 2016, EPRI has been working with DOE, the United Kingdom's Nuclear Advanced Manufacturing Research Center (AMRC), and advanced reactor manufacturer NuScale Power to develop and test technologies to build reactor pressure vessels more quickly and cost-effectively.

In particular, the collaborators have worked on powder metallurgy-hot isostatic pressing (PM-HIP), which involves atomizing metal alloys into a powder, placing the powder into a metal mold, and using high temperatures and pressures to consolidate the powder into solid components. The researchers also have advanced electron beam welding, which fuses two metal sections together by focusing a high-intensity energy beam on the junction. Unlike traditional welding, electron beam welding doesn't require filler material and can be completed in just one pass. The research has already demonstrated the potential to reduce welding time by 90 percent and costs by 40%compared to traditional approaches.

Improving manufacturing reduces plant costs as well as risks. "Components take so long to manufacture, and there are only a few places that make them.

That is a big risk for a project," said Stover. "With new technologies, you can make a reactor vessel in less than a year and bring in more equipment suppliers. That creates a more robust supply chain and reduces the risk because nobody wants a component that takes years to make."

Driving Collaboration and Demonstrating New Reactors

EPRI is also deeply involved with speeding the development of advanced nuclear reactor technology. In part, EPRI's role is to help coordinate the work being done at national laboratories, universities, and individual reactor companies to avoid the duplication of efforts.

This is important because it is time-consuming and expensive to obtain materials certification to be used in advanced reactors. "We have an advanced reactor materials development initiative, which works to qualify these high-temperature materials. This is a critical gap for high-temperature plants because there are not many qualified alloys for high temperatures in nuclear applications today," said Stover. "For any one material, it can cost $15 million to qualify for a nuclear application, so you want to do it collaboratively."

Other ongoing research initiatives EPRI is spearheading include developing a technical basis to decouple the section of the plant where nuclear energy creates steam (known as the nuclear island) from the balance of the plant that creates electricity. This would allow faster construction, dramatically decreasing the cost of building an advanced nuclear power plant.

"Because of how robust these new designs are, you don't need to rely on anything outside the nuclear island to shut the plant down," said Stover. "If something happens in the turbine island, that doesn't have an impact on the nuclear part of the plant. Our work is to show that it doesn't have an impact on the safety of the nuclear plant. If we can do that, then a huge portion of a new plant becomes a commercial project and can be built fast."

Another EPRI project just getting underway is investigating the automation potential of a wide range of tasks at nuclear power plants. This could optimize the staffing for these new reactors and improve efficiency.

EPRI is also involved with several DOE-funded demonstration projects, including one with Kairos Power, the Oak Ridge National Laboratory, and Materion Corporation. The project will demonstrate a 140-megawatt reactor fueled by TRISO that is expected to be operational by 2026. Another project brings together EPRI, Southern Company, and TerraPower to demonstrate a pilot molten chloride fast reactor, which uses liquid salts as both coolant and fuel.

Taken together, the demonstration projects and research can accelerate the deployment of advanced nuclear reactor technologies.

EPRI Technical Expert

Craig Stover

A Collective Approach to Safe Used Nuclear Fuel Storage

For the past decade-plus, the Extended Storage Collaboration Program has provided the technical basis for long-term storage and transportation

By Chris Warren

The search for a final storage solution for the nuclear fuel that powers U.S. reactors has been long and convoluted, and it is nowhere near a conclusion. In 1982, Congress passed the Nuclear Waste Policy Act, which tasked the U.S. Department of Energy (DOE) with locating a repository for the nation's used nuclear fuel.

In 2002, former President George W. Bush and Congress gave the green light for Nevada's Yucca Mountain to become the final storage location for tens of thousands of tons of spent nuclear fuel. By 2010, however, plans to permanently store used nuclear fuel and high-level waste at Yucca Mountain were canceled. There is no indication that the decision will be revisited anytime soon.

The elimination of any prospect for final disposal of spent nuclear fuel at a repository had immediate implications for nuclear power plant operators. "In the U.S., the original plan was to store the fuel in a spent-fuel pool underwater, where it cools, until the DOE had an underground repository ready and they came and got your used fuel," said Robert Hall, who manages EPRI's Used Fuel and High-Level Waste Management Program. "When that didn't happen, utilities realized they would run out of room in their fuel pools and knew if they wanted to continue to operate their reactors, they would need a place to store used fuel."

The Importance of Long-Term Dry Cask Storage

In response, nuclear power plant operators had to pivot to come up with a new storage solution. In the U.S. and other countries, that has meant turning to dry cask storage.

Dry cask storage is nothing new. Dry cask storage containers are sealed metal cylinders that are typically enclosed in a concrete or metal shell. These storage containers have long been used on-site at nuclear reactors to store fuel that has cooled sufficiently after a few years in a spent fuel pool. The original idea was that the containers would eventually be transported to an underground facility for permanent storage.

Photo courtesy U.S. Nuclear Regulatory Commission

"Dry storage was meant to be interim and temporary before final disposal," said Hatice Akkurt, an EPRI technical executive who leads the Extended Storage Collaboration Program (ESCP), which was formed in 2009 when it became clear that dry cask storage was no longer a temporary solution. "Dry storage licenses were given for 20 years. Now, plant operators are looking to get extensions for 40, 60, or perhaps even 100 years."

ESCP's Mission: Establish a Technical Basis for Long-Term Dry Cask Storage

ESCP's formation acknowledged that a range of new research would be required to fully address long-term dry cask storage issues. In many ways, the dynamic is similar to that of nuclear reactor license extensions. "If you think about the reactor side, you have to show the technical basis and monitoring to renew their licenses," Akkurt said. "If you can do that for a reactor, you can do it for dry storage. But to get a license renewal and public acceptance, you have to show your technical basis."

To do that, ESCP has brought together utilities, regulators, equipment manufacturers, industry groups, researchers, and others to identify and conduct research and analysis that ensures the safety of long-term dry storage and transportation. Research areas have included fuel behavior and the aging mechanisms and possible degradation of dry cask storage canisters, as well as effective monitoring and inspection technologies and techniques.

When ESCP was launched in 2009, it had 39 members, all from the U.S. Since then, however, it has expanded dramatically because so many organizations are trying to gain a deep technical knowledge of dry cask storage issues. It now includes 750 members from 22 countries.

"Some countries are very similar to the U.S. because they have been dealing with dry storage issues and are nowhere close to final disposal, and ESCP has been recognized as a forum to bring together experts," Akkurt said. "Some of the countries are just starting on this journey and want to learn from lessons learned and experiences, and some of the other countries are not even close to getting started but know they will eventually deal with this and want to be proactive."

Even countries that aren't relying on extended dry cask storage have joined ESCP. For example, Sweden relies solely on a centralized wet storage facility, where it is holding all of the nation's used fuel until disposal. But Sweden sees the value of ESCP membership because the group's research addresses relevant topics, including improved understanding of spent-fuel behavior and thermal fuel modeling.

A History of Pioneering Research

A small subcommittee of ESCP members determines research priorities. Other subcommittees are then formed to complete the actual research.

Over the years, ESCP research has fundamentally changed industry understanding of dry cask storage. For example, one of the first research projects recommended by ESCP was about high-burnup spent nuclear fuel. Burnup is essentially a measure of how much energy has been produced by a fuel assembly and is measured in gigawatt-days per metric ton of uranium. For those concerned with long-term dry cask storage, burnup levels are important because they impact the spent fuel's temperature and radioactivity.

Dry cask storage containers must be able to withstand high-burnup levels, both when they are stationary and when they are being transported. In the U.S., the Nuclear Regulatory Commission (NRC) reviews dry cask storage designs and establishes temperature and radioactivity limits for the spent fuel they contain. "Temperature is very important for the canisters and for your fuel integrity," Akkurt said.

ESCP helped launch a high-burnup fuel demonstration that involved measuring the actual temperatures of the spent fuel in a cask. Those measurements were then compared to the modeling used to determine temperature limits. The results were not what the industry expected. "This was a big surprise for the entire industry and regulators. The actual measured temperatures were substantially lower than the model simulations," Akkurt said.

Access to real-world measurements has many implications. "First, it tells you that concerns about the effect of high temperature on fuel cladding during storage are much less than originally thought," Hall said. "Second, you have a lot of margin. What can you do with margin? It means you can move fuel out of spent-fuel pools quicker and don't have to cool it as long. It means you can load canisters more efficiently. There are lots of things you can do with margin once it is identified."

Other ESCP research initiatives have helped improve dry cask storage inspection techniques and technologies, including the use of robotics. Another subcommittee is working to increase understanding of canister corrosion and cracking mitigation and repair.

ESCP's collaborative nature is particularly valuable, says Ned Larson, a project manager with DOE who works on nuclear technology issues. "The Department of Energy really appreciates the EPRI leadership in pulling together so many entities for ESCP so we can work together on our very important technical issues," Larson said.

Photo courtesy U.S. Nuclear Regulatory Commission

Tangible Benefits and Looking to the Future

ESCP-led research has real-world uses and benefits for nuclear power plant operators. Lessons and insights gathered through this research help inform license extension procedures. They also help enhance worker safety and reduce used-fuel storage costs. For example, robotic inspection can drive down the costs of periodic canister inspections by 90%.

A more nuanced but very real benefit of ESCP's decade-plus of activities is that lessons learned inform new priorities and deeper insights. "Our task committees and task groups change based on knowledge improvement," Akkurt said. "Sometimes our knowledge improves and it leads to more questions. That knowledge eventually leads us to more opportunities to improve dry storage."

ESCP's future research priorities will be determined by the most pressing needs of the industry. While these will vary from country to country, all of the work is ultimately about establishing a solid technical basis for the safe long-term dry cask storage and transportation of spent nuclear fuel.

"In Sweden, you are worried about transportation to your disposal sites. Right now, in the U.S., there is an effort to centralize storage. So instead of each site having its own interim storage, this would bring spent fuel from different sites before it is eventually transported to final disposal," Akkurt said. "You need to have the technical basis for all of those things."

EPRI Technical Experts

Hatice Akkurt, Bob Hall

Understanding Voluntary Conservation

EPRI research explores opportunities and challenges facing utilities pursuing conservation not driven by compliance

By Chris Warren

There was a time when longleaf pine forests dominated the landscape across the southeastern United States. In the early 1800s, the ramrod-straight, evergreen conifers covered over 90 million acres from Virginia to Texas.

As the U.S. grew, longleaf pine trees were coveted for many uses. The wood itself was used to build homes and shops across colonial America, while the pitch, tar, and turpentine made from pine tar kept wooden ships afloat. Harvesting the trees combined with clearing forests for farms and settlements nearly wiped out longleaf pine trees altogether. At one point, only 3 % of the original 90 million acres of longleaf pine forests remained.

As longleaf pine forests disappeared, so too did the abundant and diverse ecosystems the trees anchored. However, the remaining longleaf forests still provide habitat to over half of the 1630 plant species found in the southeastern U.S. and to animals ranging from the ubiquitous white-tailed deer to the endangered indigo snake, red-cockaded woodpecker, and gopher tortoise.

Company Culture and Business Interests Driving Voluntary Conservation

With a long history of operation across the southeastern U.S., Southern Company has witnessed the decline of the longleaf pine. This decline ultimately prompted the utility to take action, though the task was daunting.

"We decided to embark on a significant collaborative conservation effort to restore these vital ecosystems. We understood how difficult it would be to significantly increase the acreage of an entire forest ecosystem, but also knew the conservation benefits of the longleaf ecosystem were meaningful on many fronts," said Joe Drumm, natural resources manager at Southern Company. "Easily attainable conservation opportunities are nice, but that should not be the driving factor."

Southern Company's commitment to longleaf forest conservation has been significant despite the challenges. The utility is one of numerous public and private organizations working with the National Fish and Wildlife Foundation to fund the Longleaf Landscape Stewardship Fund, which supports projects that conserve over 350,000 acres of longleaf pine habitat and the species that rely on the forests. Between 2004 and 2020, the utility invested over $8.7 million to support the fund's programs.

Besides the significant investment, Southern Company's longleaf pine conservation effort is distinguished by being voluntary. In most cases, utility conservation is driven by the need to comply with state or federal regulations, particularly the Endangered Species Act (ESA).

By sharp contrast, Southern Company's commitment to longleaf pine conservation–along with many other voluntary conservation measures, including watershed protection throughout Alabama, Georgia, and Mississippi and migratory bird conservation–flows out of a corporate culture that prioritizes the natural environment and the communities that benefit from it. "These are the places where we spend the weekend with our families hiking and fishing," said Jesalyn McCurry, voluntary conservation manager at Southern Company. "I think it is simply that we are stewards of the communities that we serve."

Southern Company's commitment to voluntary conservation is also driven by a belief that these efforts can result in more efficient and less impactful deployment of energy infrastructure. "It's no secret, when you are looking at the complex work a utility undertakes, that we have the potential to touch a lot of our natural resources," said Drumm. "Whether we are constructing a solar installation, operating a wind farm, or deploying modern grid infrastructure, performing work in an ecosystem that's thriving is less impactful as compared to one that is in an imperiled state. Compromised ecosystems are much more fragile than healthy ones. Our goal is to operate our business without permanent impact to our natural resources."

For the species and the ecosystems Southern Company seeks to help, what really matters is that voluntary conservation can make a big impact. The total area of longleaf pine forest has nearly doubled from its low point—an achievement that has cascading benefits. "We are making headway. And because we are, the new habitat has aided in the recovery of several species," said McCurry. For example, last year, the U.S. Fish and Wildlife Service (USFWS) proposed to reclassify the red-cockaded woodpecker from endangered to threatened because its population has stabilized.

EPRI Research Into Challenges and Opportunities for Voluntary Conservation

Every utility has its own unique reasons for pursuing (or not pursuing) conservation efforts that aren't mandated by the ESA or other regulations. In an effort to better understand what motivates utilities to engage in voluntary conservation and to pinpoint some of the barriers and challenges, EPRI conducted a survey and in-depth interviews with the 17 utilities that belong to EPRI's Endangered and Protected Species Program. The utilities represent about 30 % of the total megawatts generated by EPRI members and 21 % of all generation across the U.S.

"Sometimes, as a utility, you have to do something, like obtain a permit or buy habitat because you are building a transmission line. That is not voluntary," said Christian Newman, an EPRI technical executive who led this first-of-its-kind research into voluntary conservation. "We really wanted to understand all of the other conservation work that's not about compliance as a way to chronicle it because it's not measured and to find ways to encourage more of it."

In the research, EPRI defined voluntary conservation to include:

- **Candidate conservation agreements with assurances (CCAAs):** These agreements with the USFWS are designed to conserve species that are at risk of being listed under the ESA. The agreements spell out measures an entity can take to avoid facing any additional legal restrictions or obligations if a species does end up being listed.

- **Candidate conservation agreements (CCAs):** These agreements mirror CCAAs except that they do not provide any legal assurance that a participant won't face added restrictions or obligations if a species ends up being listed under the ESA.
- **Safe harbor agreements (SHAs):** SHAs reward private landholders who take specific actions to help an endangered species recover with assurances that the USFWS won't require additional management activities. A SHA also allows a landowner to return the property covered by the agreement to the so-called "baseline conditions" that existed prior to the agreement once it expires.
- **Other activities to conserve at-risk or listed species:** These include any actions a utility takes that are not mandated under the ESA or covered by a CCAA, CCA, or SHA.
- **All other voluntary conservation activities:** These are any actions not taken for purposes of compliance with the ESA or any state conservation laws or programs. They include activities like Southern Company's contributions to the Longleaf Landscape Stewardship Fund.

Why Utilities Pursue Voluntary Conservation

Beyond providing helpful definitions of voluntary conservation, EPRI's survey and follow-up interviews illuminated both drivers of this conservation and hurdles to conducting more of it. Virtually all of the companies that participated in the survey engaged in conservation that was not dictated or recognized by the ESA, including everything from building bird nest structures in transmission towers to conducting surveys of species beyond what ESA permits require.

Overall, the report found several common drivers propelling utilities to engage in voluntary conservation efforts. The primary reason utilities pursue voluntary conservation is that they can see direct benefits to their primary business of producing or delivering electricity. These business benefits fall into two categories: lower operations and maintenance (O&M) costs and reduced utility risks.

Here are some ways voluntary conservation can potentially lower O&M costs:

- Protecting an at-risk species before it is listed as endangered has the obvious conservation benefit of helping the species itself. However, it also can avoid the potentially high cost of compliance required once a species is listed under the ESA.
- Moving the status of a species from endangered to threatened can lead the USFWS to exempt utility activities from requiring an ESA permit. This eliminates the work and costs involved in the permitting process.
- Moving a species off the endangered list eliminates the cost of ESA compliance. While conservation steps may still be required, compliance with the time-consuming and expensive ESA permitting and consultation requirements is not.

Voluntary conservation can also help mitigate the risks utilities face when listed or at-risk species are present. For example:

- Voluntary conservation initiatives can lessen long-term regulatory risk under the ESA. For instance, utilities surveyed by EPRI said that enrolling in a CCAA—which guarantees no additional ESA obligations if its terms are met—was a primary motivation for voluntary conservation.
- ESA-related risk is also reduced by the mitigation credits utilities receive for voluntary conservation efforts. These credits provide a clear path to ESA compliance and don't require a utility to uncover other options during the permitting process. Survey respondents also said that voluntary conservation provides more control over future ESA compliance, delivering more flexibility and better terms in negotiations with the USFWS.

When bottom-line benefits accrue, just about all utilities are eager to pursue voluntary conservation. But a utility's business type often dictates its willingness and capacity to pursue voluntary conservation. "Our research really highlighted the big distinction between the different types of utilities and the unique hurdles they may face," said Newman.

At a big-picture level, here's what EPRI's research found:

- Because electric cooperatives are member-owned, the interest of owners in voluntary conservation and their willingness to pay for it dictate the initiatives they pursue.
- Public utilities are nonprofits, which means voluntary conservation must be funded with O&M budgets. Unless it directly mitigates risk or lowers O&M costs, voluntary conservation can be challenging. The exception is when conservation is an explicit part of the utility's mission. In those cases, public utilities can invest in voluntary conservation that doesn't have a clear bottom-line benefit.
- Investor-owned utilities have the most latitude to invest in voluntary conservation. Because they earn profits, investor-owned utilities have the flexibility to use O&M dollars or money from profits to fund conservation. Additionally, voluntary conservation with no clear bottom-line benefit is also driven by shareholder and investor pressure.

Voluntary Conservation at a Cooperative

Tri-State Generation and Transmission Association is a Colorado-based not-for-profit cooperative with 45 members. Though Tri-State doesn't participate in any formal ESA programs, the utility is active in a range of voluntary conservation efforts.

One is the Yampa River Fund, a collaborative effort that provides funding to support aquatic habitats along the 250-mile river, which is an important part of the Colorado River system. Tri-State is also an active participant in Colorado's Ranching for Wildlife program, pursuing wildlife habitat improvement and increased public access to private lands for hunting and environmental recreation.

In these and other voluntary conservation initiatives, a common theme behind Tri-State's involvement is that the efforts seek to address multiple objectives. Grants awarded by the Yampa River Fund in 2021, for instance, include forest restoration, design, and engineering to improve recreation, trout habitat improvement, and the release of reservoir water to benefit both the environment and neighboring communities. The Ranching for Wildlife program is similarly multi-faceted, helping to promote improved livestock grazing, wildlife habitat management, and youth hunting programs on over 1.2 million acres of private ranchland across the state.

The fact that voluntary conservation participation is concentrated in the northwest Colorado region that Tri-State operates in and serves is a big reason the cooperative supports both. Ultimately, though, the choice of which voluntary conservation efforts to assist with financial and staff resources comes down to what the cooperative's members want.

"It ties back to our business model. We are a member-owned organization, and the purpose of our existence is to provide power to the members that own us," said Chris Reichard, senior environmental policy analyst at Tri-State. "We are a reflection of our members' interests and values, and a lot of our members are in rural areas, so there is a linkage to agriculture and ranching. Conservation that blends into those areas tends to be of more interest."

While Tri-State can certainly point to successes, Reichard says different approaches could encourage more voluntary conservation. One idea is to move away from the approach used in both CCAs and CCAAs of encouraging voluntary conservation by promising more straightforward compliance if a species receives protection under the ESA. "Pain avoidance will only draw in so many people," said Reichard. "It could be helpful to create incentives where utilities and landowners want to participate regardless, which could happen with the ability to sell conservation credits. I also think programs that give landowners a menu of options rather than a prescribed framework of what they have to do would help."

TVA and the Power of Collaboration

For the federally owned Tennessee Valley Authority (TVA), voluntary conservation efforts are aided by environmental stewardship being included in the public utility's mission. "Our mission is low-cost power, economic development, and environmental protection," said Travis Henry, a certified wildlife biologist with TVA. "That third part is so critical because our conservation activities used to be funded by appropriations, and eventually Congress said you have to pay for it through power sales."

The result is that voluntary conservation projects sometimes have to compete for money with other ESA compliance work. Because funds are limited, TVA partners with other organizations to pool resources and expertise when it pursues voluntary conservation. "What works best is when a number of stakeholders are interested in the same species," said Henry.

One example of such a partnership is the ongoing voluntary conservation effort to preserve the sicklefin redhorse fish. The species lives in the Hiwassee River and Little Tennessee River systems as well as in a handful of reservoirs created by dams.

Its numbers have declined over the years due to a wide range of factors, including pollution runoff, erosion that leads to silt-covered stream bottoms, and the operations of hydroelectric generation facilities, which can fragment the fish's habitat. The USFWS declared the fish a candidate for the endangered species list in 2005.

Since then, a group of organizations including TVA, Duke Energy Carolinas, the Eastern Band of the Cherokee Indians, and the state governments of North Carolina and Georgia have banded together to conserve the sicklefin redhorse. In particular, the organizations collectively signed a CCA with the USFWS to pursue proactive conservation activities aimed at keeping the fish from being listed under the ESA.

Photo courtesy U.S. Fish and Wildlife Service Southeast Region

Since taking effect in 2015, the ten-year CCA has triggered many activities. Conservation steps taken include the management of reservoir releases to minimize negative impacts on the fish, collecting and fertilizing fish eggs for hatching and release into streams in North Carolina and Georgia, and ongoing studies and monitoring of sicklefin redhorse population size, movements, and lifespan.

One important lesson is how much more can be accomplished when like-minded organizations work together. "It allows us to use our limited resources to effect greater conservation," said Henry. "When you develop a partnership, each partner can devote a limited amount of resources that together afford a positive outcome for a species."

EPRI Technical Experts

Christian Newman

About EPRI

Founded in 1972, EPRI is the world's preeminent independent, non-profit energy research and development organization, with offices around the world. EPRI's trusted experts collaborate with more than 450 companies in 45 countries, driving innovation to ensure the public has clean, safe, reliable, affordable, and equitable access to electricity across the globe.

Together, we are shaping the future of energy.

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