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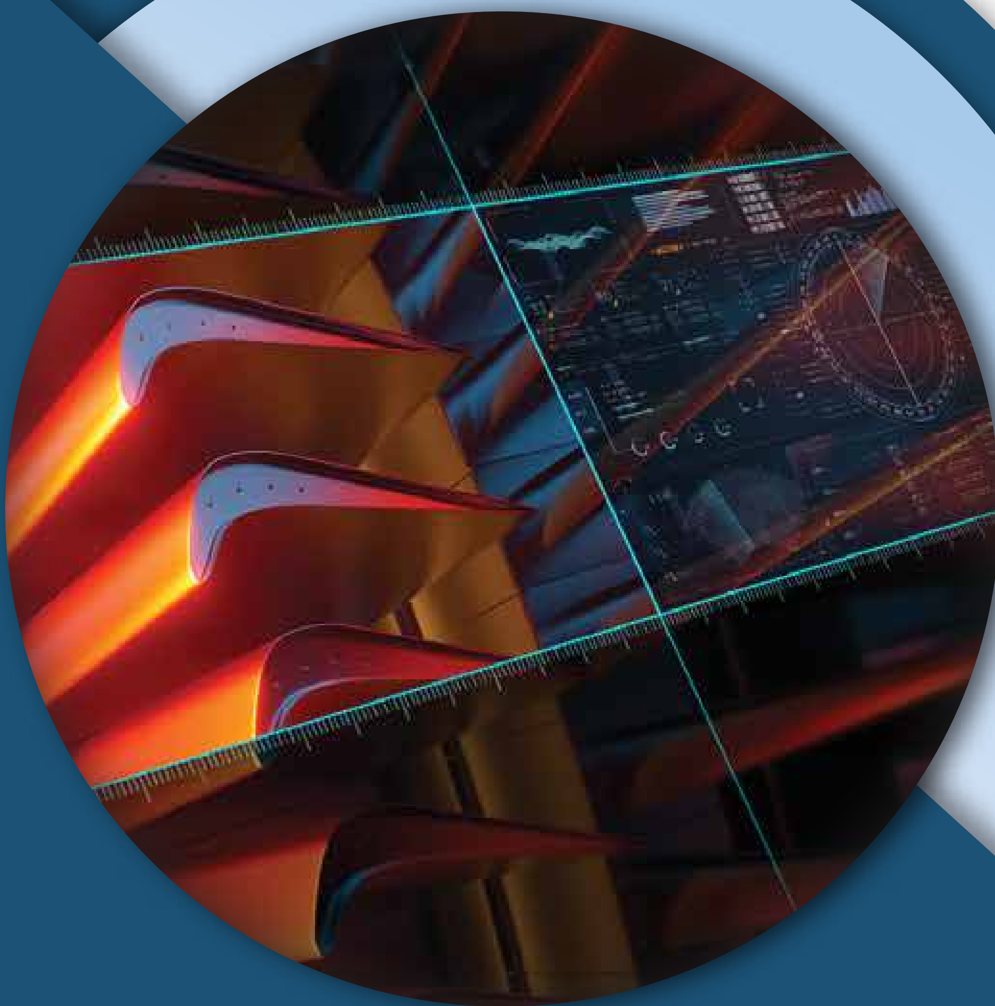
From Dependence to Reliance: Gas Turbine Maintenance in Korea



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Racing Against the Next Storm: Utilities Accelerate Grid Resilience Efforts

EPRI joins with the Ad Hoc Group, Latitude Media, and CenterPoint Energy to host the upcoming Power Resilience Forum—an event focused on the utility industry's unique grid resilience challenges and opportunities.

By Chris Warren

For people in the Houston area, Hurricane Beryl had an immediate and lasting impact. By the time Beryl reached Houston, wind speeds reached as high as 84 miles per hour at Houston-Hobby Airport, and downed trees and power lines left 2.7 million people without power. A recent report by the Kinder Institute for Urban Research at Rice University estimated the storm caused between $2.5 billion and $4.5 billion in property damages, and that the lives of 1 in 8 of the area's residents were still "very" or "somewhat" impacted.

The storm was also a catalyst for change for CenterPoint Energy, which is the transmission and distribution utility (TDU) serving the Houston area. At the time Beryl hit Houston in July 2024, CenterPoint had already submitted a system resilience plan to regulators for approval. "It became clear after the event that the pace of that resilience plan wasn't going to meet expectations," said Jason Ryan, executive vice president at CenterPoint.

In August 2024, CenterPoint launched the Greater Houston Resiliency Program, and in January of this year, the utility submitted a new Systemwide Resiliency Plan to regulators. The initiatives aim at building the most resilient coastal grid in the nation. The plan has many elements aimed at bolstering the grid to withstand the impacts of extreme weather events, like Hurricane Beryl. For example, it includes the segmentation of the distribution grid and the installation of automation devices that can self-heal and restore power without the need for utility worker intervention.

This was a direct lesson from Beryl, as CenterPoint was able to restore power for approximately one million people within the first 48 hours after the storm. "That tells you it was not heavy construction work or heavy damage to facilities. It was the equivalent of going into a breaker box at home and flipping a switch," Ryan said. "If the system can heal itself and you avoid those million customers being out in the first instance, then the men and women who are so good at restoring power can devote their time where they are needed most."

Other components of the plan include undergrounding over 50 percent of CenterPoint's distribution system, elevating nearly all substations above the 500-year floodplain, and installing approximately 130,000 distribution poles to withstand stronger storms and winds. To clarify, the utility's resilience plans prior to Beryl included some of the same initiatives as the updated version. What changed, however, was the pace of implementation, scale of work, and use of technology. For example, instead of a gradual rollout of distribution system segmentation, the updated plan accelerates segmentation so that 100 percent of the distribution circuits serving the densest concentration of customers is completed in three years.

Similarly, CenterPoint's Systemwide Resiliency Plan significantly speeds up vegetation trimming cycles from every five-and-a-half years to every three years—an especially important step given CenterPoint's service territory along the Gulf Coast is both heavily populated and densely vegetated. Since accelerating trimming after Beryl, year-over-year vegetation-caused outages have fallen by three percent.

Although CenterPoint's plan has many components, what distinguishes it is its sense of urgency. "There's no silver bullet, it's a collection of things," Ryan said. "We know what works. We just made the decision that we want to pick up the pace of the work before the next hurricane and hopefully have a materially different outcome next time because we've sped up the pace of getting these projects done."

A GROWING SENSE OF URGENCY

CenterPoint is by no means the only utility with a sense of urgency about improving the resilience of its grid. Load growth is increasing rapidly due to demand from data centers, domestic manufacturing, and electrification. As the need for electricity to propel economic growth and societal well-being

Houston, TX / licensed from Adobe Stock

increases, so too do the stakes of operating a resilient and reliable grid.

But the growing sense of urgency isn't just about the increasingly pivotal role electric power is playing in everything from winning the artificial intelligence (AI) race to boosting manufacturing jobs. The increased focus on resilience is also a rational response to the frequency and severity of extreme weather events, like Hurricane Beryl. According to the National Centers for Environmental Information (NCEI), the U.S. averaged 23 billion-dollar weather events annually between 2020 and 2024.

Extreme weather events have direct impacts on the residential and commercial customers of utilities. According to the most recent data from the U.S. Energy Information Administration (EIA), American customers experience an average of about 5.5 hours of annual power outages. The North American Electric Reliability Corporation's (NERC) most recent reliability assessment highlighted weather stresses as a primary risk to a resilient grid. At a recent Federal Energy Regulatory Commission (FERC)

Supercell Thunderstorm / licensed from Adobe Stock conference, NERC President and CEO Jim Robb characterized threats to grid reliability as a "five-alarm fire."

The reality of extreme weather's threat to the grid has prompted a stronger pivot to adaptation measures designed to help the power system withstand high winds, extreme heat and cold, and other extreme weather events.

"In the past couple of decades, the industry focused heavily on mitigation—deploying renewables and zero-emission technologies to prevent extreme weather from worsening," said Julia Hamm, partner at the Ad Hoc Group, a firm that helps climate tech startups accelerate growth. "The reality today is that we are seeing a rise in the frequency, intensity, and more widespread instances of both extreme weather events and wildfire events. In our industry, we refer to it as resilience. But it really is about adapting—changing how we plan and operate the grid in this new reality, which is only going to get worse as opposed to better."

Utility and regulatory activity in response to growing resiliency threats is accelerating. For example, states such as California, Oregon, and Washington require utilities to regularly file wildfire mitigation plans, whereas states like Texas and Florida require storm preparedness plans. Pressure is also coming from investors, many of whom now factor climate risk into their utility investments.

An evolution in how grid resilience is measured is also underway. While traditional SAIDI and SAIFI metrics remain in place, groups such as IEEE are actively investigating potential changes to these metrics. For example, California and other western states are developing frameworks that aim to quantify the effectiveness of resilience investments in reducing risk. Other metrics include the amount of time it takes utilities to restore critical loads or for all outages on a system to be addressed.

BRIDGING THE GAP BETWEEN UTILITIES AND TECHNOLOGY PROVIDERS

As extreme weather becomes more severe and frequent, many utilities are investigating a growing menu of technology solutions that promise to aid their adaptation and response efforts. However, some obstacles prevent utilities and technology providers from collaborating to pilot and deploy solutions for detecting wildfires and other extreme weather events. Utilities are often overwhelmed by the sheer volume of grid resilience-focused technologies to evaluate. For their part, technology providers are new to the long and often complex utility procurement process.

New approaches are emerging to foster more efficient and impactful collaboration between technology companies and utilities. One way technology providers can help utilities is by working together to present a unified solution to resiliency challenges, says Hamm. "How do you make it seamless for the utility. It needs to become a seamless approach to solving the utility's problem as opposed to the utility having very siloed solutions and vendors who aren't coordinating," Hamm said.

Utilities can help accelerate this process by proactively defining the resilience challenges they would like technology companies to help solve. In 2023, Pacific Gas & Electric (PG&E) released a list of its most challenging technical and operational challenges and urged technology companies to offer solutions and the opportunity to partner with PG&E to develop and implement them. More recently, the utility hosted a three-day Innovation Pitch Fest, where technology companies with solutions to reduce wildfire risk and other challenges could present their ideas and compete for up to $25 million in funding, as well as a pathway to co-develop and scale their solutions into PG&E's systems.

"This is a way to prevent both technology companies and the utility from wasting a lot of time talking about things that don't actually solve the problems that matter most to a utility," said Hamm, who was formerly president of the Smart Electric Power Alliance (SEPA) and the founder of RE+, the largest energy trade show in North America. Other ways Hamm believes utilities and technology companies can collaborate more effectively on resilience are described below.

Opportunities for Utilities and Technology Companies to Collaborate on Resilience

Have a plan to scale before launching a pilot: Pilot programs are necessary to test new technologies, but they should begin with a detailed plan for full integration if successful. "That plan should say we're piloting it for this purpose, and here are the success metrics," Hamm said. "The plan should describe what the broader rollout would look like if the pilot is successful, where the budget would come from, and the regulatory filing it would be in."

Learn from one another: Not every new technology needs to be uniquely piloted at every utility. To accelerate adoption, utilities should proactively share lessons learned from their deployments of resilience-enhancing technologies.

Engage regulators early: It's not just utilities that need to learn about and get comfortable with novel technologies. Reaching out to regulators early to educate them can expedite approvals if a utility decides to move forward with adoption. "Bring the regulators into things very early in the conversation and actively educate them about the problem statement. What is the need for new technology, and what are the different available solutions?" Hamm said.

Consider alternatives to a rate case: Resilience investments deliver long-term benefits. Because of that, including them in a single-year rate case can be problematic because of the emphasis on quick payback. There are alternatives, including a multi-year rate, which allows the cost of investments in resiliency to be spread out over multiple years. Another option is to include resiliency investments as a separate rider to provide more flexible cost recovery outside a general rate case. Another option is to issue bonds backed by ratepayer revenues, allowing the expense of resilience investments to be spread out over decades.

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CREATING SPACE FOR COLLABORATION

One sign of the maturation of resiliency in the power sector is the emergence of venues for utilities to share knowledge and connect with technology providers developing solutions. For example, the Power Resilience Forum (PRF) will take place in Houston from January 21 to 23, 2026. The event is being presented by the Ad Hoc Group and Latitude Media, sponsored by CenterPoint, and in collaboration with EPRI.

Although resilience-focused events have proliferated in recent years, PRF was established to address the specific needs of the power sector. "We are seeing events where resilience is just a small sliver of the programming and others that are hyper-focused on topics like wildfires," Hamm said. "The gap we saw was there was nothing in the middle that was power sector specific and focused on how the rise of extreme weather and wildfire events is changing how we have to plan and operate the grid."

EPRI will present a half-day Climate READi workshop on January 21, where attendees will learn about the tools and strategies to address and manage the physical climate risk to the power system. Many utilities and technology companies will share their perspectives and experiences on effective ways to bolster grid resilience, including presentations by Duke Energy, Xcel Energy, CPS Energy, Edison International, and Morgan Scott, EPRI's Vice of Global Partnerships and Outreach. "It is really intended to be a big umbrella of attendees from a power sector standpoint," Hamm said. "That means getting all of the right stakeholders in the room, from the utilities to the technology companies to the regulators, investors, insurers, and the credit rating agencies."

What does success look like? To Hamm, it's if utilities share what works well and other utilities replicate their success. Another metric of success is the presence of ongoing engagement among the broad ecosystem of stakeholders attending the event. Hamm also hopes that getting people together can generate fresh new ideas about how to improve resilience. "Hopefully this strategic level conversation spurs ideas that people hadn't yet been thinking about and really sort of gets the wheels turning on what needs to change," she said.

As utilities confront the reality that extreme weather will only intensify, events like the Power Resilience Forum represent a necessary evolution—from isolated efforts to collaborative strategy. The question is no longer whether to invest in resilience, but how quickly utilities can implement solutions before the next storm hits. For CenterPoint and utilities across the country, the race is on to build grids capable of withstanding what's coming next.

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From Hours to Minutes: How AI is Transforming Nuclear Reactor Head Inspections

By Chris Warren

To adequately grasp the expertise and extraordinary focus that analysts inspecting nuclear reactor vessel head penetrations must have, it's necessary first to visualize miles of data. Robust inspections of reactor vessel head penetrations are a key part of ensuring the safety of pressurized water reactors (PWRs). Reactor vessel head penetrations are small openings in the thick steel lid at the top of a nuclear reactor that allow long metal tubes to enter the reactor, enabling operators to control the nuclear reaction.

These penetrations must be rigorously inspected because they are exposed to intense heat and pressure. Traditional non-destructive evaluation (NDE) inspection of the penetrations involves ultrasonic testing (UT), where high-frequency sound waves are used to look for cracks and defects. To do that, a probe is moved over the inside surface of the reactor vessel head penetrations to capture ultrasonic data—basically snapshots of sound waves bouncing off the metal.

Photo courtesy EPRI Labs Ultrasonic Testing

That's when the work of the UT analyst begins. It is their job to review the equivalent of four miles of UT data for the 60 to 80 penetrations in each reactor vessel head. Their task: find the tiniest indication of abnormalities. The overwhelming majority of data an analyst will review has no signs of problems. Indications that warrant closer inspection will be found on just one or two lines of data, comprising about a quarter inch over four miles of normal-looking information.

The reasons why the work of a UT analyst is so challenging are not surprising. While analysts are skilled and experienced, they are still human, and their inspection work needs to be completed while a reactor is offline for maintenance, which adds time pressure to their task. “There’s going to be fatigue,” said Thiago Seuaciuc-Osorio, an EPRI Senior Technical Leader. “They have to work in shifts 24 hours around the clock and go through these miles of data, one click at a time. It makes a difference if they’re at the start or the end of the shift because it is hard for anyone to maintain focus for hours.”

A JOB FOR AI?

EPRI’s Materials Reliability Program (MRP) released strategies aimed at mitigating inspection errors. One of the mitigation strategies was to reduce analyst distractions. Another was for analysts to review all the data for a single penetration in one sitting, mitigating distractions and reducing fatigue. These include suggesting that analysts review all the data for a single penetration in one sitting—a process that a report conducted for the Nuclear Regulatory Commission (NRC) by the Pacific Northwest National Laboratory (PNNL) estimates takes about 90 minutes. Although potentially helpful, the sheer volume of information analysts must review also makes these inspections an ideal candidate for assistance from artificial intelligence (AI).

Indeed, the basic idea is that AI can focus human expertise on the data where it is most needed by taking on the monotonous, time-consuming, and low-value work of scanning oceans of data to pinpoint the anomalies that merit closer attention. “Most of the data doesn’t have anything of concern. Faults are rare,” Seuaciuc-Osorio said. “AI can do the easy job and leave the hard work for the inspectors.”

PART OF A LARGER EFFORT TO MODERNIZE NDE WITH AI

EPRI’s work on reactor vessel head penetrations is just one piece of a broader, multi-year effort to apply AI to several high-value NDE applications across the nuclear fleet. While EPRI’s research initiatives vary—also focusing on ultrasonic examinations of dissimilar metal welds, core shrouds, and core barrels—what they all share is an inspection process that involves time-consuming and technically demanding reviews of large amounts of data.

Although each inspection method has its own unique demands and challenges, the overall approach is similar—that is, to use AI to conduct an initial review, winnowing large volumes of data into more manageable subsets. The AI can then guide analysts to scrutinize the most relevant data. For core shroud and core barrel inspections, EPRI is also pursuing automated length-sizing capabilities, allowing analysts to spend more time interpreting flaws rather than characterizing them.

In addition, separate EPRI research is exploring how to support manual UT, a fundamentally different process because it generates no encoded record. And beyond ultrasonics, EPRI is developing AI to assist with visual inspections of reactor internals, using video data to highlight areas of potential interest.

Taken together, these efforts seek to standardize analysis and maintain high inspection reliability even as experienced analysts retire and the demands on NDE programs increase. Importantly, the work also aims to direct the cognitive efforts of analysts toward the most mentally demanding tasks. “Humans are really good at the cognitive part—

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much better than AI," Seuaciuc-Osorio said. "AI reduces the cognitive load, but more on the easy, monotonous part, not the difficult part that really requires human expertise."

HOW AI ASSISTS WITH UPPER HEAD PENETRATION INSPECTIONS

EPRI's work on reactor vessel upper head penetrations is the first of these initiatives to reach full field deployment.

The AI model's job is to identify potential flaws or aberrations for the analyst to examine. To do that, the model needs to be trained on data that helps identify potential anomalies. Put more simply, the model is a finely tuned filter designed to detect even the smallest signs of irregularities. To do that, the model was trained using field data from canceled or decommissioned components, which were supplemented with virtual flaw augmentation to expand the diversity of examples.

By having AI perform an initial review of the data, the model significantly reduces the amount of data that analysts must evaluate. During field trials, Seuaciuc-Osorio said the flag rate averaged around 3 percent of total data, even with the model tuned conservatively toward detection.

Importantly, the AI is not a self-learning system once deployed. After the model is qualified, the model is "frozen," meaning it provides the same output for the same data indefinitely. That stability is essential for regulatory compliance. As Seuaciuc-Osorio noted, if the model continued to evolve in the field, "qualification would be impossible," because the approved version would no longer match what is used in practice.

A MILESTONE DEPLOYMENT IN SWEDEN

EPRI worked with U.S. utilities to validate and improve the technology—well in advance of the recent focus on AI. For example, both Constellation Energy and Tennessee Valley Authority both received 2024 Technology Transfer Awards for their collaboration with EPRI to test AI's ability to support inspections. Through field trials, which were conducted separately from formal inspections, analysts experimented with the tool, provided feedback, and helped shape updates to enhance its usability and workflow.

These field trials helped confirm the tool's reliability. They paved the way for a landmark deployment in 2025 at two units of Vattenfall's Ringhals plant in Sweden—an effort that both validated the technology and established an important regulatory precedent.

Sweden uses a formal process for approving new inspection methods, including those that use AI. As part of that process, the method must pass two steps: an **open qualification,** where inspectors test the approach on practice pieces they're allowed to study ahead of time, and a **blind qualification**, where they must find flaws in similar pieces *without knowing where the flaws are*. These practice pieces—called **mockups**—are specially designed sections of metal that contain known flaws, allowing qualification bodies to evaluate whether an inspection method is effective. Because the Ringhals plant didn't have its own mockups, EPRI shipped over the U.S. mockups created through its Materials Reliability Program. After reviewing the technical details, the Swedish qualification body evaluated the mockups and approved them for use in the qualification process.

The Swedish utility made a bold choice: they intended to use AI as a primary examination tool, meaning the AI would screen all data before analysts viewed it. "We thought this was kind of an aggressive first step," said Leif Esp, an EPRI Program manager who worked with Vattenfall to integrate AI into its inspection process. However, Vattenfall was motivated by a clear goal—to reduce outage time by dramatically decreasing the number of hours analysts spent manually reviewing encoded UT datasets.

During qualification, the AI first had to prove it could identify every known flaw in the blind test samples before analysts were allowed to review any data. Once it demonstrated 100% detection, the flagged areas were handed over to the human examiners, who had access to the entire dataset, including the areas that had been flagged. The engineers then completed their portion of the test. According to

Esp, the results underscored the tool's reliability and the potential effectiveness of combining AI and human oversight. "Everybody who took the test ended up passing with the AI," Esp said.

Vattenfall then used the system in two consecutive outages at Ringhals. Initially, analysts manually double-checked all data because they didn't trust the AI model's accuracy. "The analysts reviewed 100 percent of the data," Esp said.

But within several days, the analysts were confident the AI wasn't missing anything. By the second outage, the utility fully leveraged the AI from the start. According to Esp, the AI-aided inspection reduced the overall examination time and improved the efficiency of the examination process for the UT analysts.

The accomplishment was also historic. The Ringhals deployment was the first example of any AI application in a nuclear power plant that required regulatory approval. The use of AI was not only a technical success, but it also demonstrated the feasibility of formal qualification pathways for future AI-enabled NDE tools.

LOOKING AHEAD: EXPANDING AI'S ROLE IN NDE

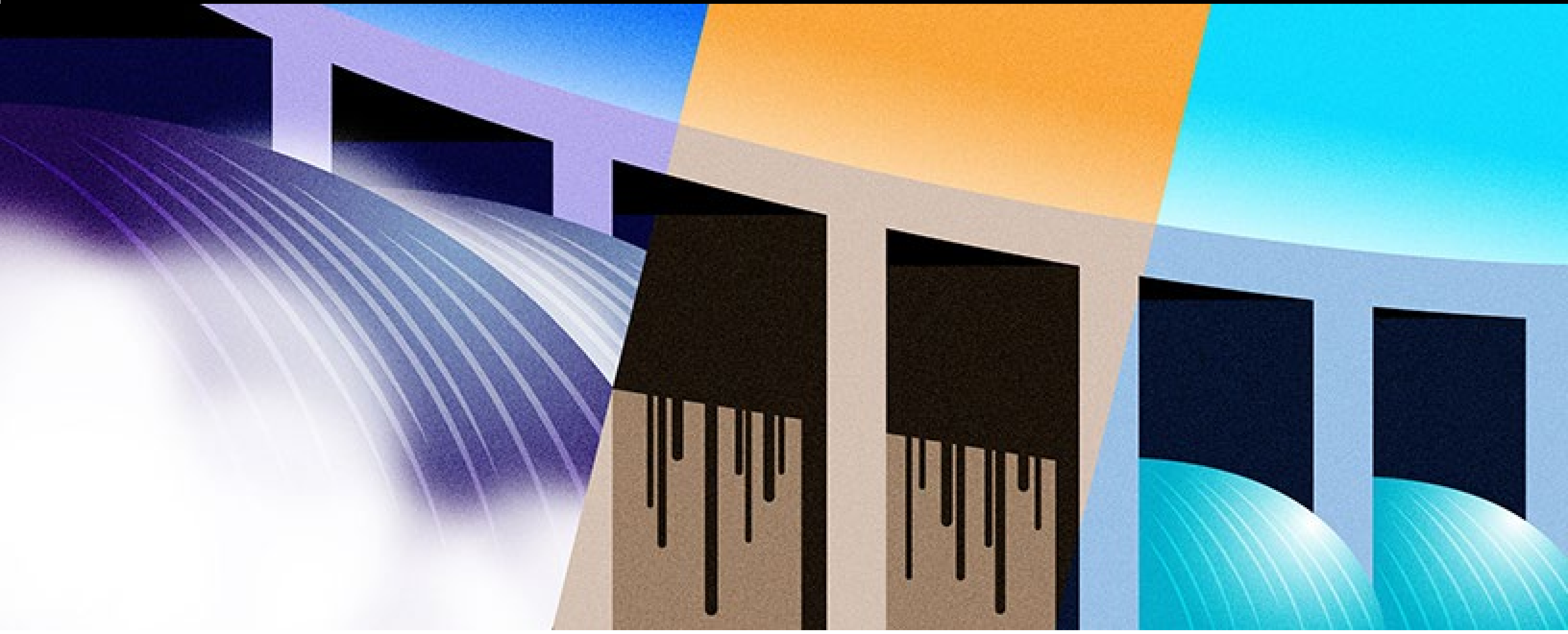
EPRI's next steps build directly on what was learned at Ringhals and through earlier U.S. trials. Work continues to enhance AI models for dissimilar metal welds and core shroud inspections, including the collection of additional field data. Prototypes for manual UT assistance are planned for demonstration next year, and utilities are beginning to examine how AI-supported visual inspections may improve consistency and reduce review time. International collaboration is also increasing, with European partners expressing interest in adapting qualification approaches used in Sweden.

Regulators, meanwhile, are signaling their support for the current use cases, which keep analysts in the loop. Future visions of fully automated analysis, where there is no human review, would require substantial additional evidence and regulatory changes. But for now, the focus remains on tools that augment analysts without replacing their judgment.

For Seuaciuc-Osorio, the ultimate goal is straightforward: ensure inspections remain reliable, efficient, and repeatable across the global fleet. The early results suggest that AI can reduce fatigue, sharpen human focus, and strengthen the effectiveness of systems that protect nuclear plant safety. "The technology does not eliminate the need for analyst expertise. It allows it to be focused where it is needed most," he said. With each successful deployment, the industry gains a clearer understanding of how AI can become a trusted partner in ensuring nuclear safety far into the future.

EPRI TECHNICAL EXPERT

Thiago Osorio, Leif Esp



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Making Climate Risk Tangible for Hydropower

By Chris Warren

The owners and operators of America's more than 2,500 hydropower plants have unenviable to-do lists. On a day-to-day basis, for example, hydropower plant operators must manage reservoir levels, maintain critical dam infrastructure, and coordinate generation dispatch based on grid demands. Because the water in hydropower reservoirs is essential for many other uses—from agricultural irrigation to recreation to drinking water—continuous coordination with other stakeholders is a necessity.

Then there are all the longer-term decisions that demand attention. With many plant components nearing the end of their anticipated useful lifespan, structures and other equipment may need significant overhauls or replacement—tasks that require careful planning, extended procurement and design processes, and efficient implementation. "All of these tasks are competing for limited bandwidth," said Dr. Mark Christian, an EPRI Technical Leader whose research focuses on hydropower.

As a result, integrating the potential impacts of climate change into planning—both for daily water management and long-term infrastructure decisions—becomes yet another challenge on an already full plate. The varying nature of climate change and its gradual, localized effects on precipitation levels make it difficult to incorporate those changes into hydropower operations and planning. "Climate change effects can seem very intangible. To many people, the specific effects and timelines can be nebulous - so what are people supposed to do about it?" Christian said.

Yet, decisions such as spillway capacity and reservoir operating rules will shape how plants perform for decades to come, and evolving climate factors may result in conditions that differ from those for which the plants were designed. However, to inform planning and potential investments, hydropower plant owners and operators require a clearer understanding of how potential future climate conditions will impact both plant performance and coordination with other sectors that depend on reliable water access.

While data is available on the anticipated impact of climate change on precipitation patterns, research has not specifically focused on how these changes may affect hydropower plants. "There's a lot of forward-looking information on how precipitation might change, and there's a lot of uncertainty there," said Dr. Jacob Mardian, a researcher in the Energy Systems and Climate Analysis Group at EPRI, whose work focuses on the impacts of climate change on the electric power sector. "But not exactly on how reservoir inflows will change".

A SCREENING TOOL FOR CLIMATE RISK

That's why EPRI's Climate READi initiative aimed to understand how a changing climate may impact the operation and performance of hydropower plants. The result of this work is a technical report, *Climate Risk Indicators for Hydropower in the Contiguous United States*, published in August 2025.

The research aimed to provide plant owners and the broader community with risk indicators relevant to each facility's characteristics and potential future climate, thereby improving understanding of plant-level impacts, prioritizing infrastructure investments, and driving proactive collaboration with stakeholders. These quantified impacts include effects on both power and non-power services offered by hydropower, including generation, flood control, irrigation, navigation, and other critical services. To provide that kind of actionable information, EPRI leveraged a comprehensive streamflow dataset from Oak Ridge National Laboratory (ORNL), which was developed under the congressionally mandated SECURE Water Act. The ORNL data provided site-specific streamflow model projections for the period 1980-2099, while data on the characteristics of individual plants were obtained from the U.S. Army Corps of Engineers' National Inventory of Dams (NID).

The streamflow projections represent a range of potential climate futures rather than a single prediction. ORNL developed 28 different projections by running seven climate models under four emissions scenarios, ranging from aggressive reductions in emissions to expanded emission rates. Each model predicts daily streamflow data that has been calibrated against 40 years of historical observations. This approach captures the inherent uncertainty in climate projections while identifying trends that appear across multiple scenarios, giving operators a sense of both the range of possible outcomes and the likely changes they'll need to prepare for.

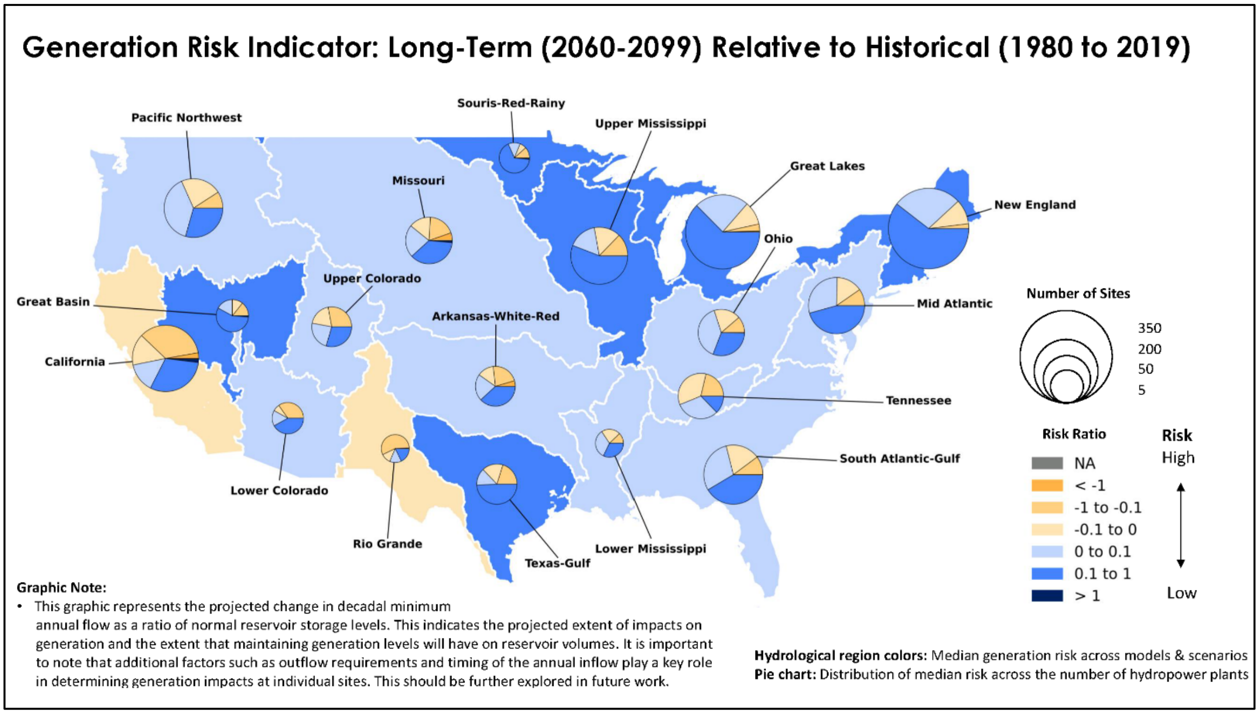
With this data, Christian and Mardian developed Hydrological Key Performance Indicators (HKPIs), metrics that connect projected hydrological changes to specific plant characteristics. At the individual plant level, this means that instead of simply calculating that the risk of drought may increase by a certain amount in the future, HKPIs consider the size of the plant's reservoir storage. A large reservoir can typically manage drought better than a small reservoir in the same location due to increased water storage capability. The researchers assessed more than 1,400 plants individually, then aggregated the results at the watershed level. This was done to protect site-specific details and to identify regional patterns.

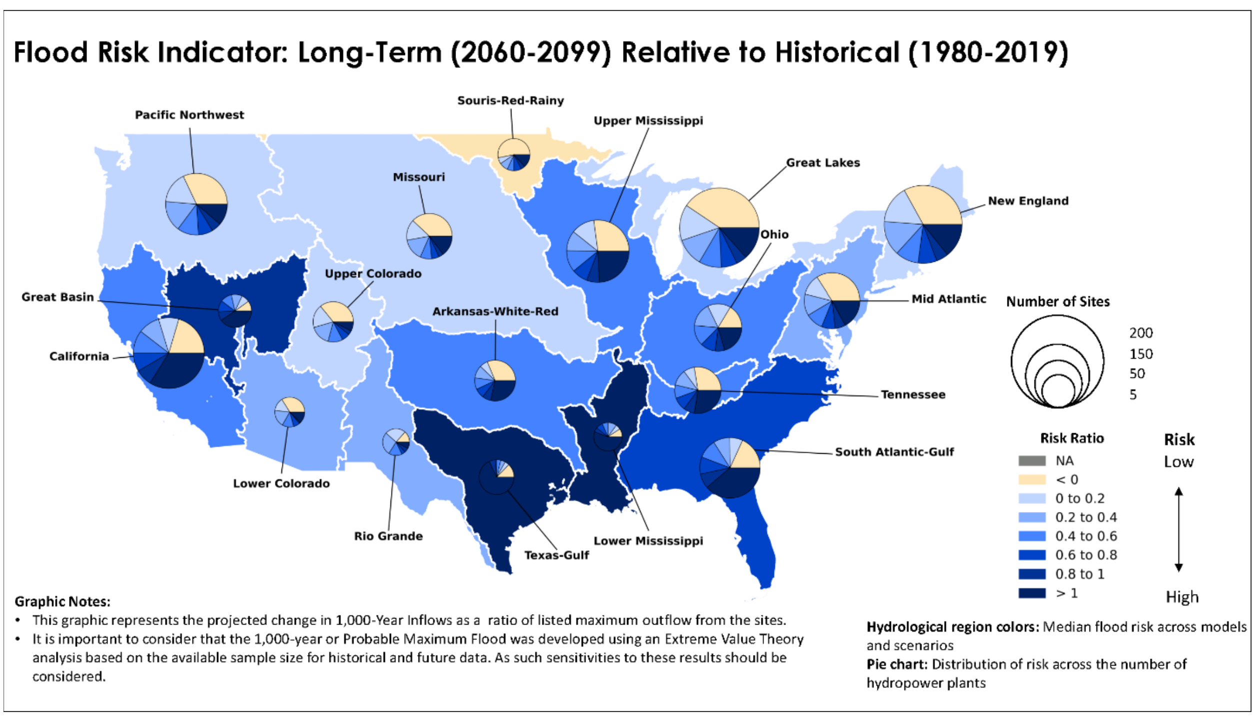
EPRI also partnered with the New York Power Authority's (NYPA) Gregory B. Jarvis Hydropower Plant near Utica to demonstrate how HKPIs could support a more detailed analysis of climate impacts. The site was selected based on data availability and operational complexity to support adaptation of the model for other sites. Christian built a detailed performance model simulating daily operations at the plant, including reservoir dynamics, spillway operations, and water releases under calculated future water conditions. The level of effort required to create this model underscored the value of applying a screening tool fleetwide to help prioritize which plants are likely to need more detailed analysis based on site-specific risk.

KEY FINDINGS: A COMPLEX PICTURE

While the purpose of the research is to provide individual plants with an assessment tool to understand potential climate risks, it also identifies more general impacts on generation, water supply, recreation, irrigation, flood control, navigation, and environmental sustainability relevant to facilities in different regions of the country. The results reveal a complex picture: climate impacts vary significantly not just between regions but even within individual watersheds. Some key findings:

Generation. Overall, EPRI's assessment found that most hydropower plants across the United States are likely to have increased annual water inflows, which could reduce generation risk. The Northeast showed the most significant increases in water availability, while the Southwest, particularly the Rio Grande Basin, faces the highest predicted risk of reduced flows. "We can see, even within this basin that has an increased risk calculation, there are some plants that have decreasing risk," Christian said, pointing to the mixed outcomes the analysis revealed. Mardian noted an important caveat to these annual risk summaries: increased annual inflows don't automatically translate to more generation if the additional water arrives during storm events or periods when reservoirs are drawn down for safety reasons and must be spilled rather than used for generation.





Flood control. A potential increase in flood risk, particularly during extreme events, is one of the most important takeaways. By examining both 100-year and 1,000-year flood scenarios, the assessment calculated increased risk of indicators in Southern, Southwestern, and Midwestern basins. "As the atmosphere becomes warmer, it holds more water, and you can get larger rainfalls, raising the risk of flooding," Mardian explained. "That's a change that is happening almost everywhere in the models." The implications of this extend from dam safety, including investments to strengthen infrastructure to withstand flooding, to the importance of operators reevaluating how longer-term weather forecasts are integrated into reservoir management.

Water supply. EPRI's assessment included 237 hydropower plants that provide municipal and industrial water and examined how low-flow conditions affect reservoirs used to supply water. Facilities in the Great Lakes and Upper Mississippi basins indicated increased risk of water supply shortages, especially in long-term projections. The interdependencies between hydropower plants, water supplies, and other uses warrant a more detailed analysis to understand the interaction between them in evolving climate conditions. "These are things we need to be studying in an integrated way," Christian said. Advanced planning is necessary to manage water needs when they are most acute. Residential and commercial water demand peaks from June to October, which is often when regions face their lowest natural water availability. For plants with limited storage capacity, even modest changes in low-flow conditions can affect their ability to serve communities and industries depending on inflow, reservoir, and operational conditions.

NEXT STEPS: COLLABORATION AND GLOBAL EXPANSION

The EPRI assessment represents a first step in identifying the potential risks to hydropower plants from an evolving climate. While the analysis calculates which plants and regions face the greatest risks, translating those insights into action requires additional work.

EPRI is working to refine the HKPIs themselves based on feedback from the hydropower community. The initial HKPIs were developed using the best available data and expert judgment; however, Christian emphasized that each service that hydropower provides—from generation to irrigation to water supply—warrants a comprehensive investigation.

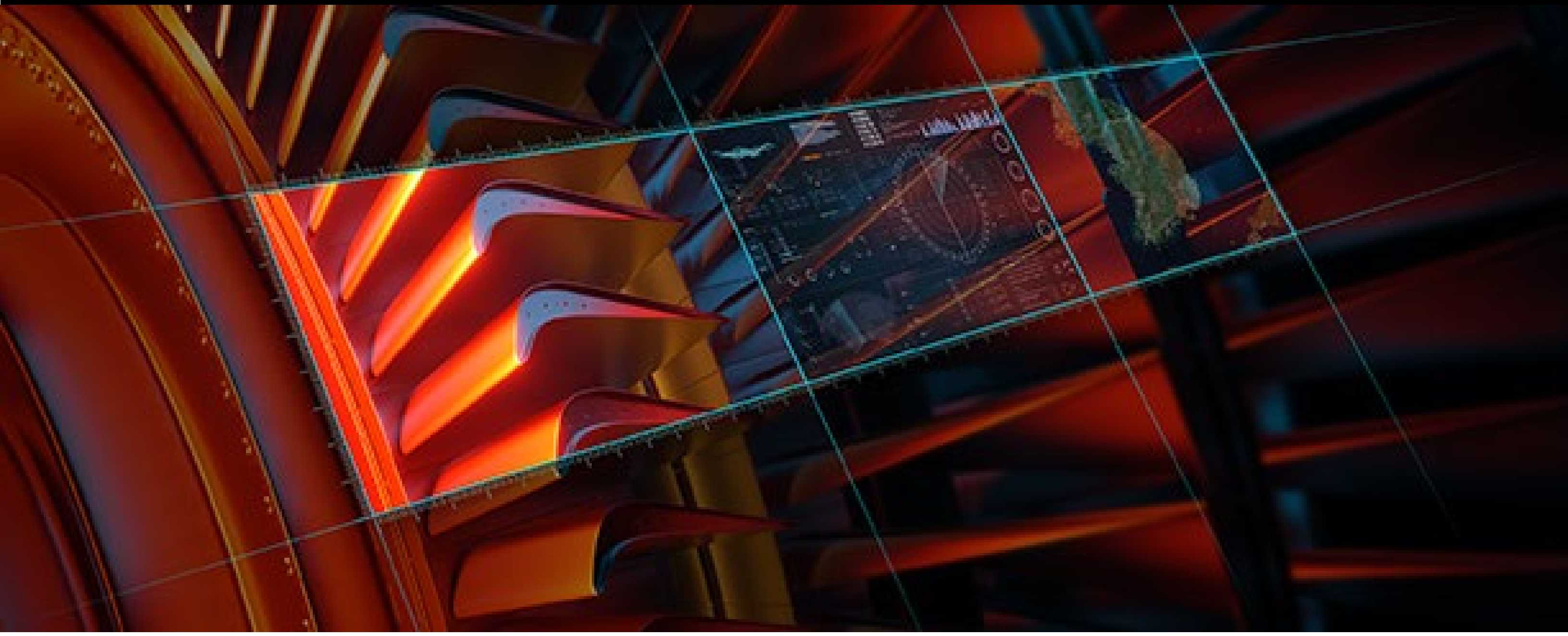
"We threw an H on the front, but really it's a KPI," he explained. "It is an indicator of broader system performance." For example, the analysis measured extreme swings in water levels—either too high or too low—to assess the impact on reservoir recreation, assuming that both could disrupt activities like boating. But the real impacts are more nuanced and require input from local communities and the recreation industry.

EPRI is also working to expand the geographical scope of the work. Christian and Mardian have proposed research to build AI-based models that would extend the climate risk assessment to hydropower plants internationally, particularly in countries that lack the comprehensive streamflow projection datasets available in the United States. EPRI is also collaborating with ORNL on a follow-on assessment examining how climate change may affect dam breach risk.

Most importantly, the work establishes a pathway from fleetwide screening to detailed site analysis. The development of the NYPA model demonstrates that, once priority plants are identified through the screening process, the detailed operational modeling approach can be tailored to those facilities. "Climate change is an uncertain and evolving science," Mardian noted. "This is not something you do once and check the box. Asset owners need to periodically monitor and update their risk assessments." The screening tool provides a framework for that ongoing evaluation, helping operators move from recognizing that climate change is happening to understanding what to do about it.

EPRI TECHNICAL EXPERTS

Mark Christian and Dr. Jacob Mardian



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From Dependence to Reliance: Gas Turbine Maintenance in Korea

By Chris Warren

Like most utilities, Korea Western Power (KOWEPO) has traditionally relied on original equipment manufacturer (OEM) service agreements to maintain its fleet of gas turbines. Keeping its advanced gas turbines operating reliably is essential for Korea Western Power. The utility depends on advanced gas turbines—whose turbine inlet temperatures (TIT) exceed 1500°C—for 50 percent of its generation and expects that proportion will increase to 70 percent in the coming years.

Though it is a widely accepted industry approach, reliance on OEM service agreements had several significant downsides for Korea Western Power. One big challenge is cost: OEM service agreements are expensive. Another is logistical. Unlike their counterparts in Europe and North America, Asian utilities are often located far from OEM service hubs.

"For companies in Europe and North America, there's probably a service depot that you can easily fly to and meet with people," said Bobby Noble, senior program manager in EPRI's gas turbine research and development (R&D) group. "Folks in Asia have a sense of isolation, especially with the OEMs based in the U.S. and Europe."

Given its dependence on advanced gas turbines, Korea Western Power began exploring ways to reduce costs while increasing self-sufficiency in gas turbine maintenance. "They are highly motivated to try to bring every bit of capability they can in-house to improve resiliency, self-reliance, and cost," Noble said.

BUILDING ON A FOUNDATION OF KNOWLEDGE

That motivation to handle as much gas turbine maintenance as possible in-house faced several challenges. Beyond the expense of launching an initiative to spearhead maintenance inside the utility, Korea Western Power also needed to ensure that its personnel had the knowledge and training to perform critical maintenance and upkeep.

EPRI was able to provide the practical knowledge Korea Western Power needed to begin gas turbine self-maintenance. Indeed, for years, EPRI had been

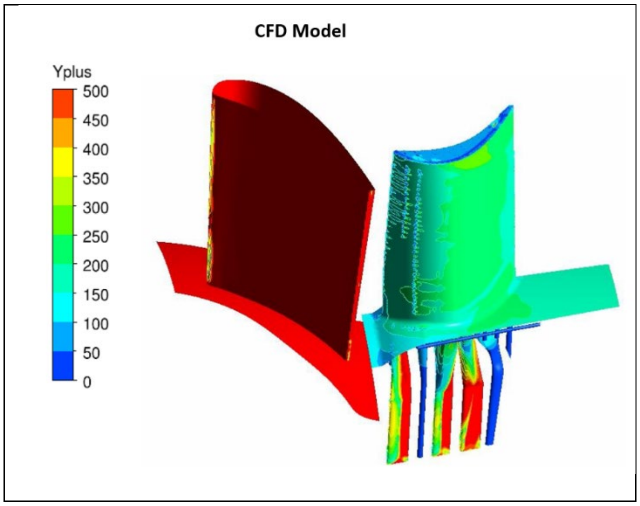

Photo courtesy Korea Western Power

developing and validating advanced repair techniques for gas turbine hot-section components. A gas turbine's hot section is where fuel (typically natural gas) burns, producing extremely hot, high-pressure gases that drive the turbine section. Made up of a combustor—where fuel and air ignite—and turbine components such as vanes and buckets, the hot section is exposed to extreme temperatures and plays a critical role in gas turbine performance.

The collaboration drew on EPRI reports, including Advanced Repair F-Class Hot Section: Blade Platform Crack Welding and Gas Turbine Repair Technology: Advanced Thermal Barrier Coating Demonstration, and adapted their findings to the specific turbine models operating in Korea Western's fleet.

One of the benefits of working with EPRI to develop repair procedures was that it would allow Korea Western Power to safely refurbish and return to service high-value blades, vanes, and combustor hardware rather than replace them at prescribed intervals, which is the standard approach recommended by OEMs.

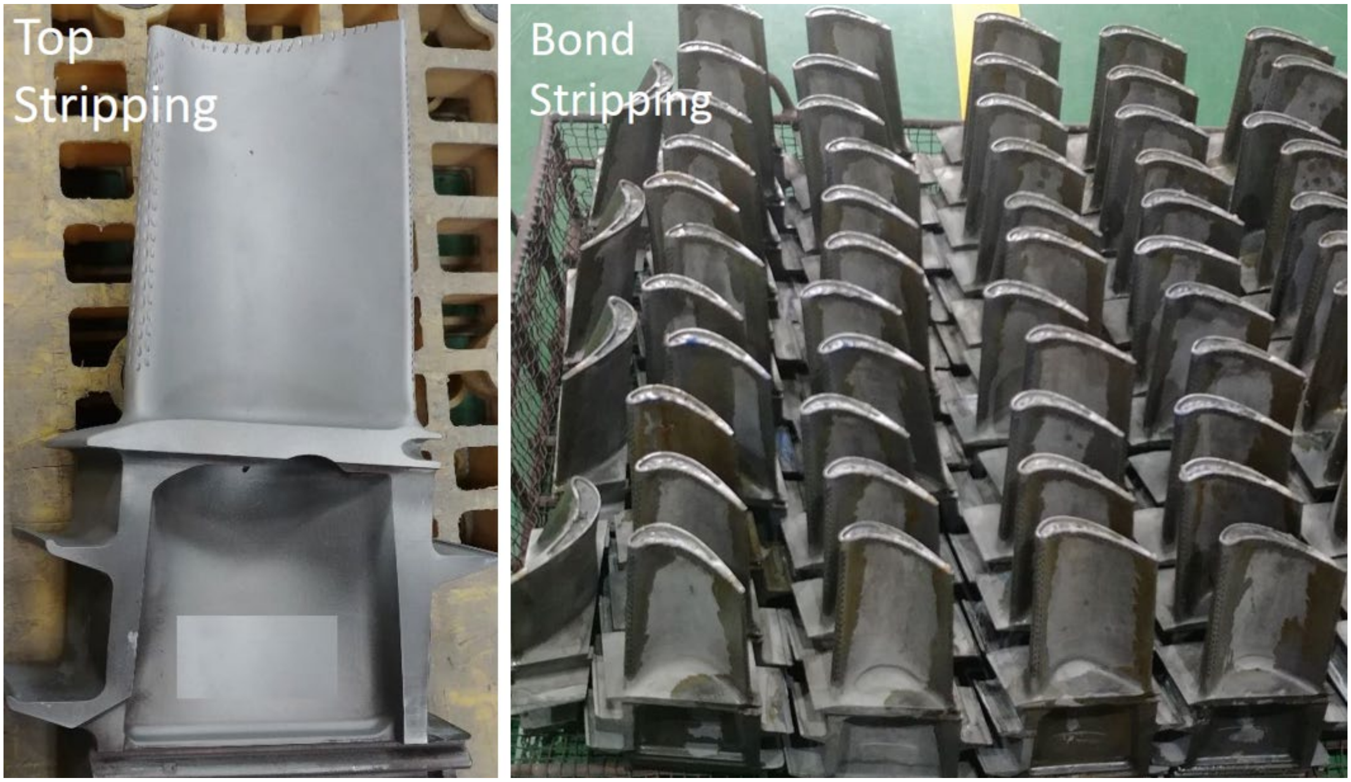

Photo courtesy Korea Western Power

A UNIQUE PARTNERSHIP

The collaboration between Korea Western Power and EPRI leveraged access to service run components to develop tailored repair procedures for the blades, vanes, and combustor designs commonly used in the utility's natural gas plants. For instance, researchers paid close attention to a range of issues—from restoring protective coatings that prevent heat damage to keeping internal cooling passages clear to ensuring that welding and heat treatment processes could strengthen metal. The underlying goal was for repaired turbine parts to perform reliably once returned to service. As part of that process, EPRI set clear pass-fail standards for refurbished parts before they could be integrated back into turbines.

EPRI's participation brought rigor and independence to an area traditionally dominated by OEMs. "No one else is really doing that in the industry," said Alex Bridges, an EPRI senior team leader involved in the work. "EPRI has been the lead on developing repair guidelines, and some third-party service providers are now using them in their work with utilities."

A BENEFIT TO THE INDUSTRY

Though EPRI collaborated directly with Korea Western Power, the intent of the work was never to develop repair guidelines that would only benefit one utility. Instead, it was about developing unit- and material-based guidance that could easily be applied to similar turbine designs. Put simply, the lessons learned at Korea Western Power were always meant to help other utilities operating comparable turbines.

The repair guidelines developed have proven to be effective. In 2023, for example, advanced turbine blades and combustion hardware were repaired using procedures developed by EPRI and Korea Western Power, and they were installed and put into normal operation. The result: the equivalent of more than 300 turbine starts during actual plant operation, without performance degradation.

In some cases, the repairs made improved component performance relative to new buckets. For example, Bridges pointed to repairs of first-stage turbine buckets—rotating blades that capture the energy of combustion gases to spin the turbine—made with advanced superalloys. By following improved heat treatment procedures developed by EPRI, the material properties of the buckets surpassed what they had been when originally manufactured. In fact, testing in EPRI laboratories demonstrated that the refurbished components had a longer expected life than new components.

TANGIBLE RESULTS AND A PATHWAY FORWARD

Korea Western Power's collaboration with EPRI has delivered financial and operational benefits. The shift away from OEM service agreements saved the utility approximately $1 million between June 2023 and June 2024. Over the longer term, cumulative savings are expected to exceed $10 million by 2030, representing a 30 percent reduction in maintenance costs across Korea Western Power's gas turbine fleet.

The ability to perform repairs in Korea rather than coordinating with a geographically distant OEM service hub has also accelerated repair timelines. This improved responsiveness and flexibility allow the utility better to align maintenance schedules with the grid's needs.

The collaboration between EPRI and Korea Western Power can also help other utilities. The combination of Korea Western Power's access to components and field intelligence and feedback with EPRI's research expertise bolsters repair knowledge and practical guidance in ways that would be difficult for any single organization to achieve. "This was an opportunity to pull bits and pieces of knowledge from across EPRI and Korea Western Power's hands-on experience together to move repair capabilities forward," Noble said.

EPRI is building on lessons learned from its work with Korea Western Power by conducting ongoing research into hot-section component failures across similar advanced turbines. The focus of the work, says Bridges, is to pinpoint the root causes that shorten component life and elevate replacement costs. Research findings will be used to refine repair strategies and operating practices that could reduce the possibility of damage happening in the first place.

By conducting neutral, third-party analyses rather than relying solely on OEM-led assessments, EPRI aims to help utilities better understand whether premature damage is driven by materials, operating conditions, upstream system issues, or interactions among those factors. Over time, EPRI expects that guidance to support a broader ecosystem of qualified third-party repair options, giving utilities more choice while maintaining rigorous technical standards.

Bridges said that work is already underway. "We're looking at some specific failures on similar units and trying to understand what the root causes are," he said. "In some cases, the hot section components are being damaged because of things happening upstream—like compressors running hotter than expected—which accelerates oxidation and ends up destroying vanes."

For Korea Western Power, the immediate focus remains execution: scaling the new repair procedures across its fleet, qualifying additional components, and continuing to build in-house expertise. Over time, those capabilities could provide strategic leverage well beyond cost savings, enabling faster response to unexpected outages, greater control over maintenance planning, and more informed negotiations with service providers.

EPRI TECHNICAL EXPERTS

Bobby Noble and Alex Bridges

EPRI JOURNAL

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Benchmarking Large Language Models for the Electric Power Sector

What EPRI's new domain-specific benchmark reveals about LLM reliability and what it means for utilities

Utilities are actively exploring large language models (LLMs) to accelerate knowledge work, summarizing technical documents, answering engineering questions, drafting procedures, and supporting decision-making. But in a safety- and compliance-critical sector, adoption requires evidence: how accurate are today's models on utility-relevant questions, and where do they fall short?

To answer that, EPRI developed the first rigorously constructed, domain-specific LLM benchmark for the electric power sector. The benchmark is grounded in real-world power-system questions, authored and reviewed by subject-matter experts across 35 domains, and is designed to be repeatable across models and time.

Four Key Insights

1 MULTIPLE-CHOICE
Multiple-choice questions (MCQs) provide a strong, but incomplete, baseline: leading models score ~83-86% on MCQs.

2 OPEN-ENDED
Open-ended questions expose a reliability gap: accuracy drops by ~27 percentage points compared to multiple-choice questions, and top models score only ~46-71% on expert-level items.

3 OPEN-WEIGHT
Open-weight (self-hostable) models are improving quickly, approaching frontier performance on MCQs (~81% in EPRI's tests).

4 WEB SEARCH
Web search improves scores modestly (about 2-4%) but introduces risks from irrelevant or misleading retrieved content.

WHY BENCHMARKING MATTERS FOR UTILITIES

Many public benchmarks emphasize broad academic knowledge (e.g., math, science, coding). They rarely reflect the operational context utilities face: equipment constraints, protection and control considerations, regulatory requirements, and real-world tradeoffs. A power-sector benchmark helps utilities understand whether LLMs can provide reliable support in their environment and where expert oversight remains essential.

WHAT EPRI TESTED

EPRI's initial benchmarking uses a three-phase methodology that increases realism step by step:

- **Phase 1 – Baseline knowledge (multiple-choice).** Models answer a large set of power-sector multiple-choice questions using only their embedded training knowledge (no external tools).
- **Phase 2 – Knowledge plus web search (multiple-choice).** The same questions are repeated, but this time the models are allowed to perform internet searches to isolate the impact of retrieval augmentation through web search.
- **Phase 3 – Open-ended short answers (with and without web search).** A subset of questions is reformulated into open-ended prompts that require models to generate free-form answers under conditions closer to real-world use.

EPRI's evaluation consists of multiple trials per model and reports confidence intervals to capture variability and stability across runs. Automated evaluation is performed using Inspect (inspect_ai), an open-source framework created by the UK AI Security Institute, with the option of SME review for higher-stakes items and edge cases.

WHAT THIS MEANS FOR ADOPTION

The benchmark results suggest a pragmatic path for utilities:

- **Start with decision-support in low-consequence contexts.** Use LLMs where errors are easy to detect and have limited impact (e.g., drafting, summarization, Q&A support), and treat outputs as decision support, not decisions, especially given the operational consequences of inaccuracies.
- **Require human oversight for safety, reliability, and compliance-critical work.** Results on open-ended reformulations indicate materially lower reliability than in multiple-choice formats, reinforcing the need for SME/engineer review.
- **If you enable retrieval (e.g., web search), validate the retrieval layer.** Average gains can mask failure modes from irrelevant or misleading sources, so pair model evaluation with retrieval-quality checks and guardrails.
- **Consider open-weight options for sensitive deployments but benchmark them.** Open-weight models are closing the gap and can be self-hosted for deployment flexibility (including secure in-house deployments). However, utilities should still validate performance, robustness, and operational fit on domain-specific tests.

WHAT'S NEXT

Future phases will build on this foundation by benchmarking domain-augmented tools and real utility use cases such as retrieval-augmented assistants, knowledge-graph-enhanced systems, and workflow automation alongside general-purpose models. EPRI will also expand applied evaluations with member utilities to measure not only accuracy, but also trust, operational impact, and integration considerations.

LEARN MORE

- WattWorks: The Power Sector's AI Benchmarking Hub
- Benchmarking Large Language Models for the Electric Power Sector

Microsoft Copilot was used to generate a draft of this article from an EPRI publication. AI-generated content was reviewed, edited, and fact-checked by an EPRI expert to ensure accuracy and quality.

About EPRI

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