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## ALSO IN THIS ISSUE:

An Untold Success Story

What it Means to Build a Garden

A Framework for Turning Nuclear  
Ambition into Action

Port of Entry for Electrification

Space-Based Solar Power Gaining Interest  
as Potential Carbon-Free Baseload Option

How Collaborative Research Bolsters  
Utility Cyber Security



## Are EVs High Maintenance?

## Table of Contents

Are EVs High Maintenance? .....	1
An Untold Success Story .....	4
What it Means to Build a Garden .....	9
A Framework for Turning Nuclear Ambition into Action .....	14
Port of Entry for Electrification.....	18
Space-Based Solar Power Gaining Interest as Potential Carbon-Free Baseload Option.....	23
How Collaborative Research Bolsters Utility Cyber Security.....	27



## Are EVs High Maintenance?

*An EPRI analysis dispels the notion that EVs are expensive to maintain.*

**By Chris Warren**

At the end of 2023 and the start of 2024, confusion was the best word to describe the public perception of electric vehicles (EVs). On the one hand, there is ample data demonstrating the rapid growth of EVs in the U.S. and around the globe. For example, Bloomberg New Energy Finance (BNEF) [reported](#) that nearly 20 percent of all passenger vehicles sold around the world in the third quarter of 2023 were EVs and that 2024 sales of EVs were expected to climb by about 18 percent.

Expanding EV choices, falling upfront costs, and generous incentives for EV purchases in the U.S. and elsewhere also drive growth in electric transport, both among individual drivers and fleet operators. At the same time, however, there has been a steady drumbeat of news stories about a supposed EV sales “slump” and “slog” and automaker [frustrations](#) about EVs sitting on dealer lots for months.

Adding to the overall confusion about the demand for EVs have been [stories](#) about insurance companies totaling EVs after minor accidents and sky-high repair costs. “I think everybody agrees there is a lot of confusion about maintenance and repair

costs for EVs versus ICE (internal combustion engine) vehicles,” said Purandhya Vij, a strategic insight engineer at EPRI. “Readers don’t know what to believe.”

### Repair and Maintenance are not the Same

Analyzing which assertions about costs are supported by data was the goal of the recent EPRI technology innovation spotlight, “[Are Electric Vehicles Expensive to Maintain? Taking a Closer Look at the Cost of EV Maintenance](#),” which Vij completed with Marcus Alexander, an EPRI transportation technical leader. The research benefitted from EPRI’s decade-plus of research into electric transportation, including extensive [analysis](#) of the total cost of ownership of EVs compared to ICE vehicles.

The goal from the start of the project was to provide clarity on the topic of EV maintenance and not add to the confusion. “The way we approached this was we wanted to make it very clear and simple,” Alexander said. “One of the strengths of EPRI is that we can provide clarity based on years of research.”



Defining what is being measured is part of delivering clarity about the comparative costs of EV and ICE vehicle maintenance. Indeed, in some news articles, repair and maintenance costs are conflated, even though they are distinct expenses. Maintenance costs refer to the expenses associated with keeping a vehicle operating reliably. For an EV, this can include replenishing critical fluids, replacing brake pads, rotating tires, and any necessary battery upkeep. In comparing routine maintenance costs, EPRI found that the light-duty vehicle maintenance costs for ICE vehicles was about 10 cents per mile, while light-duty EV maintenance costs were slightly over 6 cents per mile.

There's good reason for a higher ICE vehicle maintenance price tag. Gas-powered vehicles have more components that need to be maintained or replaced than EVs, including a transmission, timing belts, oxygen sensors, and spark plugs. Repair costs, by contrast, are entirely different and are far less predictable than maintenance expenses. Repairs are necessary when a vehicle's components are damaged or destroyed in a collision or fail due to wear and tear or a malfunction. Being clear about the difference between repairs and maintenance—including that maintenance expenses are predictable and depend on a vehicle owner's diligence while repairs are more variable and subject to chance—is the foundation of relevant cost comparisons.

### Makes and Models Matter

Comparisons of repair and maintenance costs between EVs and ICE vehicles also must consider the specific types of vehicles being compared. For example, the average collision losses for EV pickups and SUVs made by Rivian are nearly 50 percent higher than for the average gas-powered pickup truck.

But comparing a Rivian, a high-end luxury vehicle, to an average-priced ICE pickup truck or SUV is misleading. A more apt comparison for an expensive vehicle like the Rivian is a Range Rover with similar technologies and features. Using more of an apples-to-apples comparison found that collision losses for a Rivian are well below those of Range Rover, Porsche, and Mercedes G-Class SUVs. Outside the realm of luxury vehicles, an [analysis](#) by the Highway Loss Data Institute (HLDI) compared repair costs of vehicle models that offered both electric and gas-powered versions. The report's conclusion: EVs cost just two percent more on average to repair.

Part of the reason repair costs are similar is because EVs and ICE vehicles are largely similar, except for their drivetrains. "A lot of repairs have nothing to do with the powertrain," Alexander said. "There was a story about a Rivian that had a \$60,000 repair bill for a rear-end collision, but that had nothing to do with the battery. Generally, we expect repairs to be about the same across powertrains."

### The Price Impact of Newer Designs

Another factor often overlooked in comparison of repair and maintenance costs is age. Newer cars—both EVs and gas-powered—have far more sophisticated design and technologies than older models. That often translates into higher repair expenses for newer, more luxurious vehicles.

For example, replacing a windshield in older vehicles is a straightforward and inexpensive repair, costing \$150 to \$200. But replacing a windshield in a car that offers some measure of self-driving, including cruise control, can be more complicated and costly.

“With newer vehicles across the board, they’ll often have cameras mounted on the windshield or integrated into the windshield,” Vij said. “If you have a windshield replacement, you have to disassemble all the cameras, put new ones on, and complete a calibration procedure. A windshield replacement can cost \$1,500, but it has nothing to do with being an EV. It’s just that these technologies, including sensors throughout the vehicle, make everything more complicated to repair.” Even though EVs are new to the market and include the type of modern features and design that can make them more expensive to repair, HLDI found that gas vehicles are three times more likely to be declared a total loss by insurance companies after a crash.

EVs fare well in EPRI’s analysis of repair and maintenance costs. And there’s also reason to believe that the infrastructure, tools, and skills necessary to fix and maintain EVs will improve. While traditional automakers are now producing EVs, their initial growth has been driven by startups like Tesla and Rivian. Startup companies in a new industry take time to scale up a robust network of parts suppliers and maintenance and repair shops. “As these companies get bigger, they are going to have more parts and more body shops that are qualified to work on their vehicles,” Alexander said. “It’s just a matter of time and scale.”

### **EPRI Technical Expert**

Purandhya Vij and Marcus Alexander



## An Untold Success Story

*As battery energy storage proliferates, fires and safety incidents remain rare. Research and collaboration explain why.*

**By Chris Warren**

It's not hyperbole to say that April 19, 2019, marked a sharp turn in how North American utilities, manufacturers, safety code and standards developers, and other stakeholders view battery energy storage system (BESS) safety. It was on that spring day in Surprise, Arizona, that an explosion and fire at the McMicksen BESS [injured](#) four firefighters.

A later report found that the incident was caused by an internal failure in a single lithium-ion cell that began a thermal runaway. The resulting explosion and fire were not the first energy storage accidents. In South Korea, there were [28 battery fires](#) between 2017 and 2019, enough to halt the country's energy storage market. However, in the U.S., it took the high-profile incident in Arizona to prioritize BESS safety in a way it hadn't been before.

"I was at a conference a week before the Surprise, Arizona incident where everybody was saying that lithium battery technology safety is solved and that

it was a problem in South Korea only," said Lakshmi Srinivasan, principal team lead for energy storage at EPRI. "Six months later, everyone at the next version of that conference was talking about safety all the time. There has been a sea change, and now, five years later, it is a driving factor in BESS design along with the development of products and technologies that specifically focus on lithium-ion battery safety."

The industry reaction to safety incidents in Arizona and South Korea is not a story that is often told. If anything, news stories raising concerns about the safety of BESS and the adequacy of emergency response have proliferated over the past year. For example, an e-scooter [explosion](#) in New York City led to a large fire and increased scrutiny of lithium-ion battery safety. Three subsequent [fires](#) at grid-scale energy storage facilities in New York prompted Governor Kathy Hochul to convene a [working group](#) to evaluate the health and environmental impacts of battery fires and to develop fire codes and other recommendations to help prevent future incidents.

## As Storage Deployments Soar, Fire and Safety Incidents Remain Constant

Given the intense media coverage of energy storage incidents, it would be reasonable for communities where projects are proposed to question the safety of installing lithium-ion batteries. However, the larger context of BESS safety has been missing from a lot of media coverage and analysis of these individual incidents. Or, to put it more plainly, are lithium-ion battery fires the norm or rare exceptions?

In late 2023, EPRI released a Technology Innovation spotlight, [Lithium-Ion Battery Fires in the News](#), which used public data to provide insight into the prevalence of energy storage failure incidents. EPRI was well-positioned to objectively assess the frequency of battery fires. Since 2021, EPRI has maintained the publicly accessible BESS Failure Incident [Database](#), which tracks global grid-scale battery failures dating back to 2011. "We're only able to record incidents that are mentioned in the news, or that people inform us about, so we can't guarantee that the database includes all incidents," Srinivasan said. "But we have the most comprehensive data set available."

That data set paints a very different story about lithium-ion battery safety than one might infer from the news coverage. Indeed, Srinivasan and Stephanie Shaw, an EPRI technical executive, compared the average frequency of energy storage incidents and the technology's rapidly increasing deployment. "We saw that deployment exponentially increased from one gigawatt deployed globally in 2018 to 65 gigawatts in 2023," Shaw said. "Despite that 65-fold increase in deployment, you're still seeing about ten incidents globally on average. That number is not going up as battery deployments are increasing at an incredibly fast pace over the same time period."

Obviously, grid-scale batteries aren't the only energy storage technology. For the Technology Innovation spotlight, EPRI also examined battery fires and incidents involving electric vehicles (EVs) and micro-mobility sectors, including electric scooters and bikes.



**EV passenger fires are less frequent than in vehicles powered by internal combustion engines (ICE).** Fires in passenger EVs are exceedingly rare. By examining data sets from both the U.S. and Sweden, EPRI found that the likelihood of a Tesla EV fire in America between 2012 and 2021 was one in 210 million miles driven. By contrast, ICE vehicles had a fire likelihood of one in 19 million miles over the same period. The difference in fire frequency in Sweden was even more stark, with ICE vehicle fires occurring at a rate of 23 to 1 compared to EVs.

Nevertheless, the relative novelty of EV fires means they attract a disproportionate amount of media attention. Contributing to the elevated scrutiny is the fact that emergency response protocols for EV passenger fires are less well-established; EVs have not been on the road long enough for all first responders to be fully trained to respond to their unique electrical, chemical, fire, and explosion hazards. This is quickly changing, however, as standards organizations like the National Fire Protection Association (NFPA) work collaboratively with automakers, utilities, and organizations like EPRI to develop codes, standards, and best practices for effectively responding to EV fires. This work includes research and improved understanding about the best techniques to fight fires in EVs flooded during a natural disaster.

**Micro-mobility requires greater education, enforcement, and regulation.** While the incidence of fires and other failure events is small in grid-scale storage and passenger EVs, more needs to be done to improve the safety of electric bikes, scooters, and hoverboards. In fact, there were over 500 battery fires in electric micro-mobility vehicles globally between January and the end of June 2023, resulting



in 36 fatalities and 138 injuries, according to data from EVFireSafe.com. Multiple reasons help explain the comparative frequency of micro-mobility battery fires. While numerous safety standards exist for electric scooters, bikes, and hoverboards, not all manufacturers follow them. Fraudulent labeling misrepresenting compliance can occur, and enforcement is challenging. The widespread availability of aftermarket and third-party components—many of which don't meet product certification standards—also increases the risk of battery fires during charging. These risks are exacerbated and increase the possibility of injury or death because micro-mobility devices are typically charged indoors. When a fire occurs in a high-density, multi-tenant residence, the risks of injury or death are particularly acute. While it's important for micro-mobility manufacturers to adhere to safety standards, greater awareness among the public about the risks associated with using third-party components is also needed.

## A Collaborative Response

Though it is less likely to grab headlines and clicks, the story of the collective reaction to high-profile lithium-ion battery fires and explosions is both a success and still unfolding. "Any battery failure is one too many," Shaw said. "You can reduce the impact and probability of a failure, and the trend in the right direction is clear from the data. The industry has incorporated a lot of lessons learned and is improving safety regulations and the range and effectiveness of mitigation technologies. Those combined actions have substantially reduced risks."

For example, insurance companies today work much closer with energy storage developers to base premiums on comprehensive assessments of fire and

explosion risks and incorporation of clearance distances into project designs to ensure safety if an accident occurs. Since the 2019 fire, Underwriter Laboratories (UL) and the International Electrotechnical Commission (IEC) have updated their safety standards, and the National Fire Protection Agency (NFPA) introduced comprehensive requirements targeting fire safety and emergency planning for energy storage design, construction, commissioning, operations, and decommissioning in 2023.

While codes and standards are important, they are inevitably playing catchup with rapid energy storage technology development. Nevertheless, significant investment is going into identifying and preventing possible fires before they start. "There's an entire section of the industry that's focused on predictive analytics around safety to prevent these incidents. There are companies developing technology and products focused on identifying failures early, preventing them, and developing new sensing technology," Srinivasan said.

Helpful to the energy storage industry's efforts to prevent and reduce incidents and bolster the safety of first responders are EPRI's many years of research into safety-related topics. The scope of EPRI's battery safety research is sprawling and includes input and support from about 25 utilities, project developers, and insurance companies in the U.S. and around the globe. The research also benefits from the knowledge and experience of representatives from fire departments, fire safety experts, insurance agencies, academic institutions, and national laboratories.







Besides maintaining a database of energy storage safety related incidents, EPRI's work also includes:

- The development of a battery storage fire safety [Wiki](#), which provides publicly available reports and guidance that can be used by the owners, operators, and developers of energy storage to help design and build projects that reduce the risk of a fire and ensure the safety of workers, first responders, the public, and the environment.
- Creating a project lifecycle safety toolkit, including models and guidance for safely deploying energy storage. Leading practices are available throughout the entire lifecycle of energy storage projects. "We have produced materials looking at everything from system design, effective fire mitigation technologies to use and guidance about how to retrofit a system to meet new standards," Shaw said. "We also have operational tips about how to learn from and train first responders, effectively interact with stakeholders, and decommission a project safely."
- Site-specific safety assessments help storage stakeholders proactively identify and address safety concerns based on the unique characteristics of individual projects. More generally, EPRI has also published white papers delving into topics of general interest to educate the public, including the safety implications of lithium-ion battery chemistries, the differences, and impacts of battery thermal runaway compared to fire ignition, and a residential energy storage safety guide.

EPRI has also worked with a broad collection of stakeholders to develop a [roadmap](#) for future research to close knowledge gaps. For example, one near-term focus area for EPRI and its collaborators is improving the quality of publicly available data about battery fires. "One of the gaps we identified is the need for more public data sets on exactly the sort of failure characteristics and some of the gas and thermal details about how a fire happens and how it may differ depending on different chemistries and different product configurations," Shaw said. Improved data and information will also support EPRI's project life cycle safety toolkit, which already provides guidance to bolster safety at each phase of an energy storage project.

### What if Everything Goes Right? The Community Benefits of Energy Storage

One objective energy storage safety research does *not* seek is to dismiss or diminish the questions and worries people raise when battery projects are being developed in their communities. "There might be a lot of misinformation, but there are also legitimate concerns around the public health, safety, and environmental impact in the event of lithium battery fires," Srinivasan said.

The goal for battery storage developers, utilities, and other stakeholders should always be complete transparency about the low incidence of safety incidents and acknowledge what is not well understood yet—such as the contamination levels of water used to put out battery fires. An emphasis on science-based facts and transparent communication can also build trust and drive broader conversations about the community benefits of energy storage projects.

Some benefits of energy storage can seem removed from the tangible, day-to-day concerns among community residents. While it's true that energy storage enables decarbonization and provides vital grid services, for instance, communities often have more pressing economic, equity, and workforce development priorities. Energy storage developers, utilities, and others need to communicate better, listen, and engage with communities about the benefits projects can deliver and the outcomes residents seek. "What if everything goes right? What do communities get out of this?" Shaw said.

The answer depends on what communities care about, but there are many possible advantages energy storage can deliver. For example, battery storage—especially as part of a microgrid—can improve the reliability, resilience, and accessibility of emergency services in the face of extreme weather. Battery storage projects can also reduce energy bills and result in workforce education and training that can improve the financial situation of individuals and families in a community. Guidance and recommendations about how energy storage stakeholders can work collaboratively with communities to maximize the project's benefits is the topic of an upcoming EPRI white paper, *Community Benefit Planning for Energy Storage Projects*.

The story of enhanced energy storage safety in a rapidly growing industry needs to be told more frequently, emphasizing the positive underlying data and commitment to continuous improvement. But that is not enough by itself. An even better story will emerge as communities are engaged early and continuously to connect energy storage projects to the priorities they care most about.

Additional information about EPRI's ongoing collaborative research is available through the BESS Fire Prevention and Mitigation Phase III Supplemental [Project](#).

### **EPRI Technical Expert**

Stephanie Shaw and Lakshmi Srinivasan



## What it Means to Build a Garden

*LADWP's Hollywood Reservoir Pollinator Garden shines a spotlight on people.*

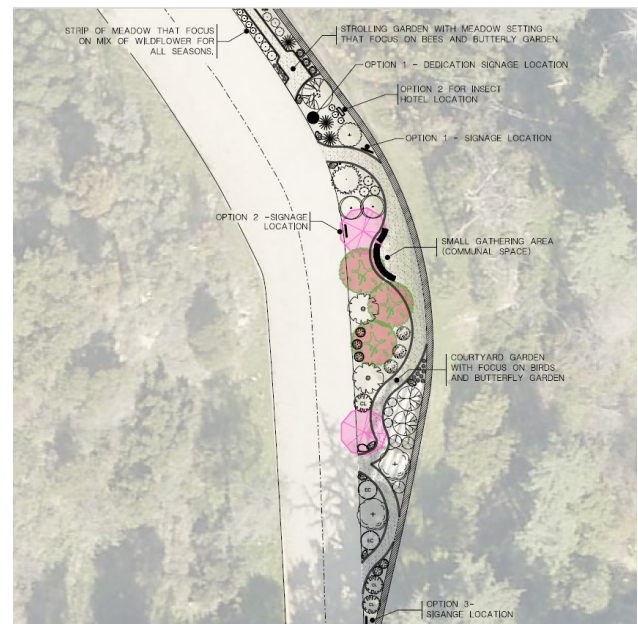
**By Chris Warren**

When Meliana Tanzil was studying landscape architecture at California Polytechnic University in Pomona, California, she already had a concrete idea about the types of projects she wanted to pursue post-graduation. Tanzil wanted to craft designs of public spaces where community members could find respite from the frenetic pace of modern living and learn more about the natural world. She also wanted to work on highly collaborative projects that elicited the best ideas from her colleagues.

Though she couldn't have known it as a student, Tanzil was describing the newly installed pollinator garden at the Hollywood Reservoir in Los Angeles, California. "When I took my major in landscape architecture, this is what I envisioned, and now I'm doing it," said Tanzil, a Senior Architecture Drafting Technician at the Los Angeles Department of Water and Power (LADWP).

The quarter-acre garden will be unveiled to the public at a ribbon-cutting ceremony on June 1, 2024. Even in a city known for spectacle, the garden is a remarkable location for an event. The garden

features meandering pathways and is dotted with teak wood benches where visitors can soak in views of the iconic Hollywood sign and the arched concrete Mulholland Dam built in the 1920s that makes the reservoir possible.



Even those who prefer to keep their eyes focused on the garden will have plenty to look at. The garden features three dozen California native, drought tolerant, and pollinator-friendly plants, which were selected because they provide essential habitat for native pollinators such as the local California Sister Butterfly, Anna's Hummingbird, and various wild bees. The plants include a mix of colors and sizes that bloom during different seasons—so that pollinators always have a source of food—and include three types of Manzanitas, Canyon sunflowers, California wild rose, jellybean red Monkey flower, and Milkweeds. Among all the hotel options in Hollywood, the Hollywood Air Bee n' Bee may be the most wild! It provides both a refuge for the important pollinators and education about their importance to visitors.

## Building on LADWP's Commitment to Sustainable Land Management

The public ribbon cutting that officially opens the garden will be a festive occasion highlighting pollinators and local speakers, including the Mayor's office, plus free native seeds and plants for people's own pollinator-friendly gardens. The bees, butterflies, hummingbirds, and other pollinators deserve the attention. Healthy pollinator populations are a critical linchpin in providing about one-third of the food the world eats, including strawberries, coffee, and the cocoa beans used to make chocolate. Unfortunately, a mix of habitat loss, climate change, pesticides, and invasive species threaten the pollinator populations the world needs.

Education about the importance of pollinator conservation is the understandable focus of the ceremony. But it's part of a larger story about LADWP's commitment to biodiversity and the



natural world. It's a story worth telling to understand how the Hollywood Reservoir Pollinator Garden came to be and to inspire other utilities eager to manage the land they own to achieve society-benefitting goals.

The genesis of the Hollywood Reservoir pollinator garden traces back to a Strategic Landholding Analysis (SLA) LADWP completed with EPRI in 2020. "The strategic landholding analysis was a way to better understand the environmental and ecological benefits of our landholdings beyond meeting our compliance obligations," said Maria Sison-Roces, Manager of Corporate Sustainability Programs at LADWP. "It was about understanding the lands and natural resources that LADWP has and what the opportunities are to manage them to achieve sustainability and other goals."

As the largest municipal utility in the U.S., LADWP manages hundreds of thousands of acres in Los Angeles, Owens, and Inyo Counties. The SLA process developed by EPRI follows a rigorous methodology, including facilitated discussions to define company goals and the use of Geographic Information Systems (GIS) to analyze and rank parcels of land for their potential to achieve utility objectives. One of LADWP's sustainability goals is to support habitat and biodiversity, especially for pollinators. With that objective in mind, the SLA guided LADWP through an analysis of its land to identify those most suitable for pollinator habitat conservation.





## A Reality Check

Once the list of potential sites was winnowed down, LADWP and EPRI looked closely at several properties to see if a project would be viable. "It was a great opportunity to sit down and, within that shortlist, figure out the reality of each of these parcels. Can we actually do something?" said Helen Grace Olivares, Manager of Property Management in the Water Operations Division at LADWP.

Even when GIS data and natural resource information about a parcel of land look promising, there is no guarantee that it will be suitable for pollinator habitat. Some properties, for instance, may require so much land restoration work that the resource requirements would be too high, or there may be legal restrictions limiting vegetation management options supporting biodiversity. To answer those questions, LADWP staff and EPRI Principal Technical Executive Jessica Fox visited several sites. Fox is a conservation biologist specializing in California species and the founder of EPRI's Power-in-Pollinators Initiative. When Fox surveyed the land around the Hollywood Reservoir, she was struck by how healthy it was.

"It was just remarkable. The vegetative community was really solid. We got there and started identifying individual species, the bees and birds and flowers, and I looked at the soil and said, 'We have to do this project,'" Fox recalled.

It was clear to Fox that LADWP's vegetation management staff was exceptionally good at supporting native plants and that building a pollinator garden would leverage skills the utility already had. "They were already managing this site well, and the more than 500 acres of habitat around the reservoir was in great condition," Fox said. "But they weren't telling anybody about it and weren't using it as an education opportunity."

Finding a better place to inspire the public about pollinators would be hard. The 3.2-mile pathway around the reservoir's perimeter, also known as Lake Hollywood and the home of the famous Hollywood sign, attracts upwards of a million tourists and local walkers, runners, and cyclists yearly.

## Commitment to Collaboration

The design and construction of the Hollywood Reservoir Pollinator Garden required both extensive selected, Tanzil began working on two garden designs.

Tanzil solicited input and plant suggestions from Noe Gomez-Romero, John Willett, and Eusebio Serna, who all work in the utility's landscape group and have deep expertise and experience working with California native and drought-tolerant plants.

LADWP ultimately settled on a natural design that mirrored the garden's surroundings. And in October of 2023, Gomez-Romero, an LADWP Park Maintenance Supervisor, and his colleagues began translating the design into reality.

Having input into the plant selection was important for Gomez-Romero, Willett, and Serna because they are acutely aware of how species will fare in the varying climactic conditions across Los Angeles. To be sure, LADWP is eager for people to carefully monitor its approach to plant selection, especially at the Hollywood Reservoir pollinator garden. "We want to provide a model for what people can do in their own gardens," Willett said. "We want to educate people about drought-tolerant landscapes that support pollinators, are easy to maintain, and are pleasing to the eye."

## Overcoming Challenges

The Hollywood Reservoir pollinator garden was completed in about five months. But its translation from initial idea to reality wasn't without hiccups—which, Gomez-Romero says, is inevitable with any landscaping project. An early challenge came after the LADWP landscaping crew assessed the area's soil. While the surrounding natural lands supported a variety of healthy soils, much of the soil in the specific location selected for the garden was heavily modified during dam construction and was now hard clay and decomposed granite.

Though it slowed the project down by a couple of weeks, LADWP opted to remove about 160 yards of the existing soil. The soil was replaced by sandy loam. "That was the most challenging part of the construction," Gomez-Romero said. "We had to dig



out the existing soil and replace two to three feet in depth so the plants would have enough room to root and thrive."

Another challenge the LADWP crew had to overcome was providing a water source to irrigate the plants. The plants selected for the garden are drought tolerant but require irrigation early in their lives to get established and healthy. "If there is no water, there is no life," said Serna, whose job it was to deliver water to the garden. Fox noted, "native plant restoration in the arid west brings some challenges, particularly in the first five years when we need to ensure the flowers bloom and reseed. We considered various options for this project, especially as a public demonstration area, but determined that targeted irrigation made sense, following a 'right rate, right place, right time' approach."

Serna oversaw the installation of a 400-foot pipe to transport water to the garden. He also worked with plumbers to incorporate a smart irrigation system, which is now standard in all LADWP landscaping projects. "The system detects how much water is being used, and it can be controlled from the computer or a phone just in case it rains or is cold and you don't need to water as much or if one of the areas needs to be watered more," Serna said. "We are working on ways to use less water and get it to plants when they need it."

California's rainy winter delayed work on the project because LADWP had to wait for the soil to dry out before planting. However, the rains also provided an opportunity to test how well the garden drained rainwater. "We weren't sure how the water would flow because the road that runs alongside the garden tends to act like a storm

diversion channel," Olivares said. "Having it rain during construction helped us identify how to avoid flooding or risk the garden washing out in the future."

Another challenge to completing the garden included the placement of two large decorative boulders. A forklift had to be brought in, and holes had to be dug to keep the boulders in place. Adjustments also had to be made once the boulders were in place. For example, one of the boulders had to be moved so that a plaque with the garden's name could be affixed to the stone's flat face. The garden is named after Cindy Montañez, a former California assemblywoman, LADWP executive, and environmental champion who passed away in 2023.

In placing the boulders, Gomez-Romero and his staff were also aware of how they would impact visitors' experience. "We needed to have it in the perfect position and angle so people could take pictures and get the boulder, the placard, and the Hollywood sign in one shot," Gomez-Romero said.

## A Passion Project

One benefit of the collaboration needed to build the Hollywood Reservoir Pollinator Garden is that it raised awareness within LADWP about the importance of pollinators. That awareness is helping to build momentum for more pollinator projects. "Initially, the focus has been more on water conservation, which remains a high priority in the region. But just in the last few years, our landscaping group has led the charge to include native pollinator-friendly landscaping, which are both drought tolerant and fire retardant. It's really about understanding our role and responsibility to care for nature and the environment, especially in our landholdings," Sison-Roces said.

In fact, LADWP's Board of Water and Power Commissioners recently passed a [Biodiversity Motion](#) that directs LADWP to institutionalize and integrate biodiversity, habitat enhancement, and nature-based solutions throughout its operations and management of assets while balancing operational needs and ratepayer impacts.

It doesn't hurt that the people who will install future pollinator-friendly gardens are personally passionate about the importance of giving back to pollinators. Indeed, Willet, Serna, and Gomez-Romero easily rattle off the names of the plants that make up their own pollinator gardens at home. For example, a partial list of the plants in Serna's garden includes a variety of Manzanitas, Lantana, Birds of Paradise, Honeysuckle, and Trumpet Vine. Willet's extensive home garden features species like the leafless Gambelia Juncea, the Island Snapdragon, four types of buckwheat, cactus, and 18 varieties of aloe. Gomez-Romero's front yard includes several different colored poppies and Skylark.

While just one garden, this project has the potential to inspire millions of local and international visitors to take action in their own homes, companies, and schools. For LADWP, this single quarter-acre garden and the SLA assessment that identified this opportunity has supported broader consideration for the intersection between pollinators, climate, and social equity at the largest municipal water and power provider in the U.S.

For the people who did the hard labor, there is an emotional connection. Even before the garden's official opening, Gomez-Romero says their work attracted a lot of interest and questions from passersby. He welcomed the opportunity to chat about pollinators, plants, and LADWP's sustainability work.

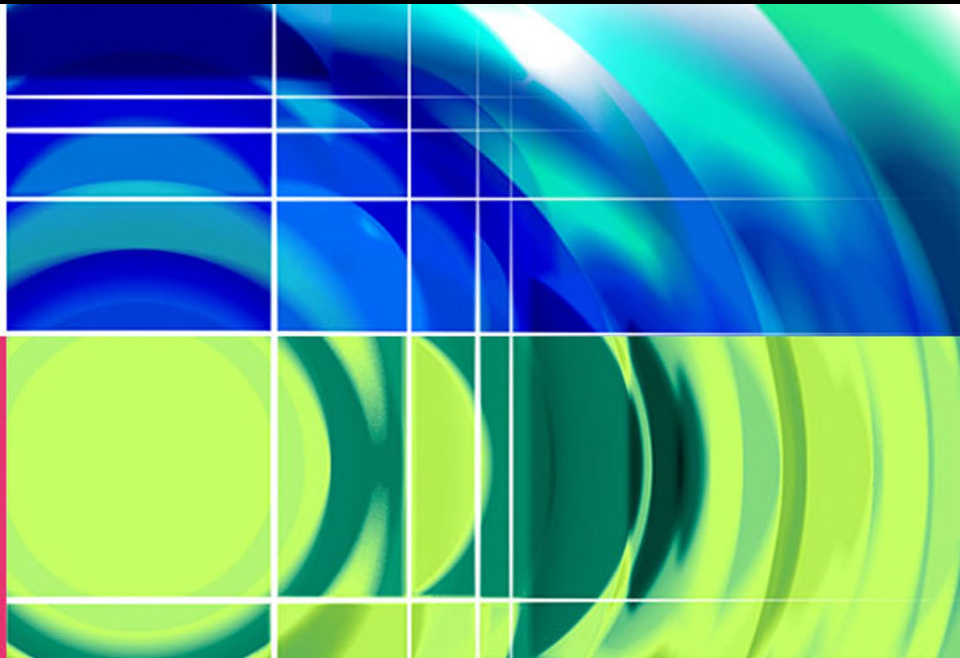
"We feel proud and excited about it and love to share what we do. We encourage people to implement gardens in their own lives," Gomez-Romero said. "People wonder what we do, and they can see here what we are doing for the city, the environment, and pollinators. People think we just provide water and power. We are also giving back to earth."

## EPRI Technical Expert

Jessica Fox



Scan the QR code to read the online article.



## A Framework for Turning Nuclear Ambition into Action

*A practical tool to drive innovation and progress will be introduced at this year's Global Forum for Nuclear Innovation (GFNI) in Miami.*

**By Chris Warren**

A recent survey neatly crystallized the fundamental challenge and opportunity faced by the global nuclear energy industry. On the one hand, 83 percent of the professionals in the nuclear sector surveyed agreed that they work in an industry full of ambition.

Today, more than ever, ambition is exactly what is needed in the nuclear sector. Already the world's second-largest source of carbon-free energy, over 20 nations came together at last year's COP28 in Dubai to [launch](#) an initiative to triple nuclear energy capacity by 2050. As the world increasingly relies on variable generation like wind and solar, nuclear is poised to provide critical supply flexibility and help meet the demand from large energy consumers, like data centers and manufacturing.

While an overwhelming majority of nuclear sector professionals agreed that their industry is filled with the kind of ambition the world needs, a nearly equal number of respondents pointed to a worrying disconnect. Indeed, 77 percent of those surveyed said there is a disparity between the ambition

animating the sector and the daily actions of people working in the industry. The chasm between the society and livelihood improving ambition in the nuclear industry and the day-to-day work and activities of those in it must be closed for real progress to be made. Put simply, ambition must be turned into action.

### Why a Tool is Important to Transform Great Ideas into Reality

But the question is how? Answering that question will be the focus of the Global Forum for Nuclear Innovation ([GFNI](#)), which will be held in Miami, Florida, June 24-27. This year's GFNI builds on the progress and momentum of the past two gatherings. The 2019 GFNI in South Korea centered on technological innovation, and identified four innovations that could drive progress. The 2022 GFNI in London focused on what constitutes an [innovative culture](#) and identified four necessary behaviors to accelerate innovation.



But, one gap that was identified at the 2022 event was the practical need for innovation tools. In other words, translating ambition into action necessitates specific tools that can be used by people at organizations of varying sizes and in diverse locations around the globe. Over the past year, a [framework](#) that can be used across the global industry as a tool to accelerate the transformation of ideas and ambition into tangible and meaningful action was developed.

The research that resulted in the framework included journeys of personal and professional ambitions as well as barriers and enablers. “We wanted to identify what ambition looks like, where it comes from, whether they are good ambitions, and how do we then get that ambition into action?” said Jon Salthouse, who was the Principal Investigator in the project and is a Consulting Partner at Prologue Communications in the United Kingdom. “What are the barriers stopping us from getting where we want to go, and, of course, what kind of solution can we provide at the Global Forum?”

## A Framework Built on Research

The imperative to develop a concrete and tangible framework for translating ambition into beneficial action is important enough that it could not be based on guesswork. For that reason, with initial guidance from the GFNI steering committee, EPRI led a five-month, research initiative to answer three fundamental questions:

- What is the roadmap that connects ambition to action?
- What are the barriers that slow down the process?
- What are the tools that enable the process?

To get answers to these questions that can be applied to the diverse set of people and organizations that constitute the global nuclear power sector, EPRI conducted a five-phase research initiative. “We went through five different layers, and every layer became more specific to the nuclear sector and provided more targeted insights,” Salthouse said. The five phases of research were:

### Phase One: Creating Conversations

To better understand what turning ambition into action means across the nuclear sector, social media channels were used to kickstart conversations and gather personal and professional stories from several countries. Respondents answered questions about whether turning ambition into action requires a catalyst or is part of a continuous process and the tools that are best for accelerating personal and professional ambitions forward.

### Phase Two: Background Reading

Background reading included examinations of behavioral models for organizational change, such as the SMART Goals Framework, which prioritizes setting specific, measurable, achievable, relevant, and time-bound objectives.

### Phase Three: Story Gathering

This phase of the research involved collecting stories about people’s successes and failures turning ambition into action. Using an interactive story gathering platform allowed researchers to gather insights from professionals in multiple industries about the specific ambition people had (like writing a book, running a marathon, or reaching sales targets), their roadmap to achieve it, and the barriers and enablers they faced. The exercise helped identify themes that exist regardless of the ambition sought. The stories revealed five common themes for turning ambition into action: communication; effective planning; adaptability; accountability; and motivation. As we will see below, these individual themes can serve both as enablers and barriers to turning ambition into action.

### Phase Four: Survey Insight

78 professionals with an average of over 20 years in the nuclear sector answered 52 questions aimed at developing a more granular understanding of the roadmap, enablers, and barriers of transforming ambition into action. The purpose of soliciting the feedback was to inform the ultimate framework developed to help nuclear professionals achieve their ambitions.

## Phase Five: Focus Groups

The final research step leveraged the insights and themes developed in the first four phases to inform questions and topics posed to 12 focus groups and interviews held with 26 participants from across the nuclear sector. The focus groups helped validate and supplement themes that emerged in prior phases of research. Four themes emerged from the feedback provided by the focus groups. They are accountability; support and feedback; bridging the gap; and behavior change.

## Putting It All Together into a Tool for Turning Ambition into Action

Past GFNI gatherings brought insights and important lessons to drive innovation. Building on that, the GFNI in Miami aims to provide a tool that will help participants accelerate innovation upon returning to their organizations after the conference.

One of the benefits of designing a framework based on extensive research is that it can dispel some preconceptions about what may have been hindering innovation in the past. “You expect things like regulation or technical challenges to be significant barriers in the nuclear industry,” said Ben Arwine, Global Innovation Effectiveness Lead, who helped develop the framework. “An ah-ha for me in this work was seeing that the things we are struggling with in this industry are more around practices of collaboration and work and project management that are being overlooked.”

The framework, which will be introduced and used at GFNI, follows three steps:

### Step One: Define the Ambition and Outcome

Lacking a clear and commonly understood ambition can derail innovation from the start. Step one of the framework involves gathering all stakeholders to collectively define the ambition being sought. This will inevitably be an iterative process, but at the end a clear ambition will outline what problem is being solved, why it’s important now, who it impacts, and how long it will take. Another component of this initial step is defining what success looks like, including how outcomes are measured, who will feel the benefits, and what fundamental improvements will come after achieving the ambition. Finally, the

first step includes crafting a narrative around the ambition that communicates what ultimate success looks like, why the ambition matters, and what role individuals play in achieving the ambition.

### Step Two: Identifying the Actions

Turning ambition into action require a lot of activity. The specific actions that result in ambition being realized will vary depending on the project—some will be complex and in need of constant reevaluation while others will be more straightforward. Step two of the framework is all about clearly establishing the actions and milestones that need to be completed to make progress towards the ambition. This involves selecting the appropriate change, work, or innovation model to achieve the ambition and conducting the strategic planning that defines and assigns the tasks that must be completed at each stage of the project. A plan for measuring, tracking, and communicating progress throughout the project must also be created and implemented.

### Step Three: Balance the Attributes that can be Barriers or Enablers

Every project seeking to achieve an ambition will be propelled by enablers and stymied by barriers. It is important to clearly identify the forces working in their favor and those that limit or stall their progress. Step three is about intentionally reviewing the list of attributes common in the nuclear industry, which was developed as part of this research, and intentionally leveraging enablers to drive progress while mitigating the negative impact of the barriers to ambition.

## Common Steps, But Execution and Context Matter

There is plenty of nuance to each of these steps. For instance, the framework research made it clear that barriers and enablers could be the same thing; execution is what determined whether they were a help or hindrance in achieving an ambition. “Some people told us if we get communication right, we are really going to be able to turn ambition into action. Communication is vital,” Salthouse said. “We also had people telling us that communication is a barrier. Nobody really sets expectations, and everything is muddy.”

The key, then, is to ensure that the attributes of a project's success serve as enablers rather than barriers. A project's context matters in ensuring an attribute is an enabler. With communication, for instance, a commitment to hear all voices and perspectives, and experiences can be invaluable in a long-term research initiative. But that same approach to communication can be counterproductive in an emergency when time is limited, and a single source of authority can accelerate action.

Attendees at the Miami GFNI will have the opportunity to learn about and use the framework. Earlier this year, at EPRI's Nuclear Power Council's general session, the framework was introduced and tested on four specific ambitions. One of the ambitions was to develop and deploy new and existing materials to support the licensing and long-term operation of advanced non-light water reactors (ARs).

Scott Hunnewell, vice president of the New Nuclear Program for Tennessee Valley Authority (TVA), attended the session. Hunnewell and his team at TVA are evaluating advanced reactor technologies and materials; many of the reactors being developed will operate at temperatures and pressures greater than the current fleet, and the materials used must be qualified to withstand those conditions.

Hunnewell and others used the framework to examine the ambition of the qualification of advanced reactor materials. "We were all new to this framework, which I think was a good thing," Hunnewell said. "It really focused us to think in new and different ways." For Hunnewell, the experience of working with the framework emphasized the critical role of communication in achieving the ambition of qualifying advanced reactor materials and identified a way to make communication an enabler rather than a barrier.

While the [framework](#) will be introduced and tested at the GFNI, its real value will be when attendees bring it back to their organizations and implement it to advance their innovative ideas. Put simply, the success of the framework is not its development. Instead, its value will be determined by the myriad ways it is applied to help translate ambition into action to benefit companies, societies, and the planet.

## **EPRI Technical Expert**

Heather Feldman



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## Port of Entry for Electrification

*How an EPRI study is accelerating emissions reductions at the Port of Los Angeles*

**By Chris Warren**

Comfort with big numbers is helpful to understand the frenetic pace of daily activity at the Port of Los Angeles (POLA). Encompassing 7,500 acres and 43 miles of waterfront, POLA handled 8.6 million 20-foot intermodal shipping containers in 2023, including over 550,000 loaded with furniture, 300,000-plus with auto parts, and more than 250,000 carrying apparel from trade partners ranging from China and Japan to India, Germany, South Africa, and Australia.

2023 was no anomaly. The Port of Los Angeles has been the busiest container port in the Western Hemisphere for nearly a quarter century. Its sprawling activities connect POLA to one in nine jobs across Southern California and almost three million jobs nationally. In total, POLA's 25 cargo terminals processed nearly \$300 billion in cargo value in 2023.

The sheer volume of activity isn't the only suitable metric to describe POLA's ambition. More recently, the Port of Los Angeles has embraced a leadership role in exploring and deploying solutions to significantly reduce both greenhouse gas emissions

as well as nitrogen oxides (NOx), sulfur oxides (SOx), and particulate matter that are associated with air quality issues for port workers and neighboring communities.

POLA's ambition to decarbonize and improve air quality is partly driven by state and local policies and regulations. For example, in 2021, the Los Angeles City Council adopted the "Zero Emissions Ports by 2030" resolution, which calls for creating zero-emission shipping corridors across trade routes and for all ships that dock at the Port of Los Angeles to be zero emissions by 2030. The California Air Resources Board (CARB) adopted a rule designed to limit a range of emissions from ships docked at the state's ports and terminals. California aims to slash economywide greenhouse gas emissions by [85 percent](#) by 2045.

"The Port of Los Angeles has a long history of environmental stewardship," said Sal Zambrano, Harbor Engineer and Chief of Design at the Port of Los Angeles. "We've been at the forefront of maritime decarbonization efforts through our Clean

Air Action Plan. Along with our governor and mayor, we've set ambitious goals and we're working hard to achieve them." In pushing towards dramatic emissions reductions, POLA also can establish a blueprint for America's other 360 river and ocean ports to follow.

"California is always the tip of the spear; we are slaying the dragon first," Zambrano said. "If we can demonstrate that we can make it work and that it's a viable solution, then others will jump in because they will know it's a cost-effective solution the industry can embrace."

## A Focus on Electrification of Cargo-Handling Equipment (CHE)

Electrification is central to POLA's strategy to reduce greenhouse gas emissions and improve air quality. Since the 1970s, many ports around the country have converted the large ship-to-shore cranes used to load and unload cargo from diesel to electric power from the grid. While cranes use a lot of electricity, many pieces of cargo-handling equipment (CHE) have yet to be electrified—offering an avenue to reduce emissions and air pollutants.

There are nearly 2,000 pieces of CHE at the Port of Los Angeles. The equipment fleet includes everything from terminal tractors and forklifts to non-road vehicles, empty container handlers, and rubber-tired gantry cranes. Clearly, any significant move to electrify CHE at POLA can only be accomplished if sufficient grid capacity is in place, which is why POLA has been working with the Los Angeles Department of Water and Power (LADWP) for years to better understand and plan for future load demands and overcome electrification challenges.

"We are interested in understanding what it's going to take to serve that load and what constraints exist from a grid perspective that need to be addressed with upgrades," said Yamen Nanne, Power Engineering Manager at LADWP. Initially, that assessment was done in-house, but there was a recognition that the staff resources and expertise required to collect data about the load demands of a wide range of CHE and assess solutions to manage peak demand were significant enough that external support was needed.

As a result, LADWP and POLA jointly funded research and analysis conducted by EPRI. The result was the technical report, [\*Zero-Emission Planning and Grid Assessment for the Port of Los Angeles\*](#), released last year. The comprehensive assessment was supported by contributions from both the LADWP and POLA, along with six of POLA's container terminal operators—who, after all, will be making investments in electrified CHE and need confidence that sufficient grid capacity will be available to keep new equipment charged.

EPRI's engagement was unique because it included input and analysis from four EPRI research programs: electrification (Program 199), distribution operations and planning (Program 200), energy storage (Program 94), and electric transportation (Program 18). The report also provides a 13-year electrification roadmap with specific steps and recommendations for reducing and eventually eliminating CHE emissions. "It started as a simple project, but based on our discussions with them, we realized that a lot of things needed to be done," said Baskar Vairamohan, an EPRI Program Manager who oversaw the project. "EPRI's expertise in off-road electric vehicle, energy storage, and grid forecasting and planning was uniquely suited to all the analysis and modeling this required."

The value of an outside perspective was important in helping both LADWP and POLA clarify potential next steps. "We really needed to bring in subject matter experts to catalog all the equipment and understand what it's going to take to power that equipment once it's electrified," Nanne said. "Once we have that information detailed and outlined, then we can do the load flow analysis that informs us what upgrades are needed on the distribution system and upstream at the substation level to accommodate all that load growth."

The rationale for a comprehensive study was straightforward. Electrification is a powerful tool for reaching zero-emission targets. However, building out the grid infrastructure necessary to serve high demand requires time and significant investments. Ensuring grid upgrades are sufficient to meet demand without overbuilding can only be accomplished with robust data and modeling. "We didn't want to build too little and be stuck not being able to accommodate zero emissions," said Chris

Brown, Chief Harbor Engineer at the Port of Los Angeles. "And no one wanted to have stranded assets where we built too much, and it turned out that was unnecessary. The EPRI report was key in getting us to that no-regret point."

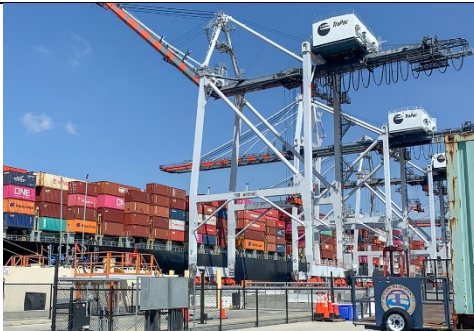
The EPRI study revealed important findings that POLA and LADWP have shared with the mayor and city council, who set policy goals and investment budgets.

**Among the report's main takeaways:**



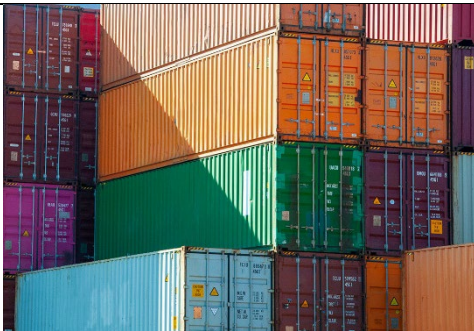
**CHE Emissions**

CHE accounts for almost 15 percent of all carbon dioxide emissions at the port, as well as 5 percent of NOx, 38 percent of CO, and about 5 percent of diesel-related pollutants.



**Charging Loads**

Potential charging loads resulting from CHE electrification would significantly increase the port's distribution system loading and require meaningful grid upgrades. More specifically, the analysis forecast increases of 191 megawatts if CHE charging was unmanaged and 128 megawatts if managed. In addition, LADWP's planned substation upgrades are not sufficient to accommodate anticipated load growth under several scenarios and would necessitate a new substation and other infrastructure upgrades.



**Peak Demand**

As the above finding indicates, peak demand from CHE can be reduced dramatically if container terminal operators implement optimal charging solutions. Managed charging can also reduce the expense of necessary grid upgrades.



**Energy Storage**

Energy storage does not yet offer an economically viable tool for container terminal operators to reduce their CHE peak loads. That could change, however, as energy storage costs continue to decline. If LADWP were to develop rates that would incentivize the deployment of storage to mitigate peak demand,

## Unprecedented Collaboration

Arriving at these and other study findings required collaboration between LADWP and POLA and myriad analyses from EPRI. One role that EPRI's analysis and participation played was to begin filling information gaps about POLA's future loads and the steps LADWP would need to take to meet them.

"When we first started some of these discussions with POLA, there were a lot of unknowns. The methodologies that EPRI used to help us quantify the cargo handling equipment provided some perspective on how we can break down that customer need and meet that load," said Peter Liang, a member of LADWP's Distribution System Development Team. "It also gives us ideas about how we can better optimize our system to manage some of the electrification demands through charging or through incentivizing certain shifts in operation."

Providing helpful insights demanded a methodical and nuanced research and modeling approach. For example, to assess the emissions reduction potential of electrifying CHE, EPRI, LADWP, and POLA first had to quantify the emissions of the existing fleet of container handling equipment. This was aided by POLA's Annual Inventory of Air Emissions [report](#), which had to be augmented with granular, equipment-level data. "It can be very complicated if you have a piece of equipment purchased in the 1980s versus a piece of equipment purchased in 2011," said Brandon Johnson, an EPRI Technical Leader. "There are very different emissions standards on equipment from the 1980s compared to equipment from ten years ago."

The electrification potential of different types of CHE also varies significantly. While electric cranes, forklifts, and other CHE are already well established or moving quickly towards maturity, other types are novel. "We were looking at equipment with serial number one," Johnson said. "That makes it a lot harder to come up with assumptions about how much energy it is going to consume, what it's going to take to charge it, and how often you're going to have to charge. There are a lot of nuances, and it's hard to truly know until it's out there in the field and being used by actual people." This is where EPRI's subject matter expertise about the energy consumption of similar electric equipment

performing similar tasks helped develop assumptions that were incorporated into load forecasts.

EPRI also filled knowledge gaps about the grid impacts of electrification and potential opportunities to mitigate them. This required detailed distribution system modeling and analysis, which was spearheaded by Jouni Peppanen, an EPRI Principal Team Leader. "At the time of the study, LADWP didn't have a model available for POLA and the surrounding area," Peppanen said. "The starting point was to implement a model by taking GIS [geographic information system] data and mapping and design documents from LADWP to find and clean up the key data." With this data, EPRI developed a detailed grid model using its open-source OpenDSS software.

With a grid model in place, it was also necessary for EPRI to calculate current and future loading conditions, both at POLA and in the surrounding area. This included the location of large loads, like electric cranes, as well as the load profiles of different CHE. "One of the big things we identified is that, based on future scenarios, you would need a new transmission receiving station," Peppanen said. "Some scenarios you can accommodate with minor changes, like transferring some of the loads from one circuit to another. But in some scenarios, significant investments were needed, like several additional circuits and miles and miles of new underground cables."

One of Peppanen's main takeaways from his work was the importance of continually updating the modeling and analysis as more information becomes available. For instance, a better understanding of terminal operator CHE electrification strategies would provide vital data for planning and executing the long-term investments needed to prepare the grid for new loads. "The LADWP team definitely can identify good ways to address the needs of container terminal operators if they know what those needs are," Peppanen said. "I think it'll be very important for LADWP and POLA to work very closely with the container terminal operators on their electrification plans because of the lead times and the costs involved with different mitigation solutions."

The work involved in developing the study provided a good baseline of cooperation between EPRI, POLA, the container terminal operators, and LADWP. As part of the study's development, EPRI conducted site visits and interviews with six container terminal operators. The insights gathered can help LADWP understand the container terminal operator's unique electricity demands. "With this study, we were able to dive much deeper into how the cargo handling equipment would be used," Liang said. "That opens up opportunities to help our stakeholders and our management understand the underlying strategies of how we can promote more electrification and how things like managed charging can help ensure any grid infrastructure provided to POLA is efficient and cost-effective."

The improved understanding of the role managed charging can play in promoting efficient electrification at POLA was the result of analysis EPRI's Miles Evans contributed to the study. "That involved developing a model of how the operators of the equipment will do their job with the equipment and when they will operate," said Evans, who is an EPRI Senior Team Lead for Energy Storage Analysis. "It also involved understanding how the equipment can be charged and what leeway exists for managing that charging."

## Translating Knowledge into Action

The rationale for the exhaustive study was never to gather abstract insights; it was to spur real action. "We don't want this report to sit on the shelf or the Internet," Zambrano said.

It's not. The findings from the report are being used to inform elected officials who make regulatory and budget decisions. For example, the Los Angeles City Council recently passed a motion requesting a report on what would be necessary from a power supply perspective to help the port increase electrification. "The EPRI study is an input to that report that we're going to be providing to the council," LADWP's Nanne said. "It's helping to keep priority on the project and giving our city council the information they need to push this forward."



Zambrano says the environmental assessment process for necessary grid infrastructure upgrades will begin soon, followed by initial design work. "The main project elements are already outlined in the report. We're expanding the receiving station, and we have to supply property for that expansion, which we are working on," Zambrano said. "Then we need to extend distribution lines to all the major container terminals and find a location where a network station will be located within each terminal." Like the report itself, all the work demands a high level of collaboration between LADWP, POLA, and the container terminal operators.

For his part, Zambrano is clear-eyed about all the work that needs to happen to help POLA meet its emissions reduction goals through greater electrification without overbuilding infrastructure. "It's going to be an ongoing process," Zambrano said. "But we're all committed to it, and I think that's one of the many beneficial results of the report."

Within EPRI, the report also provides a blueprint for how disparate research disciplines can come together to complement one another and produce insights that have immediate and tangible value. "This report is the epitome of how various programs within EPRI come together and bring multi-faceted research and modeling skills to solve a complex problem that has immediately realizable real-world benefits" Vairamohan said.

## EPRI Technical Expert

Baskar Vairamohan





Photo credit: charunwit- stock.adobe.com

## Space-Based Solar Power Gaining Interest as Potential Carbon-Free Baseload Option

*Microwave-based transmission could enable space-based solar panels to send 24/7 solar energy to base stations on Earth.*

**By Chuck Ross**

Solar energy has become a critical contributor in our efforts to transition to carbon-free electricity generation. But the issue of intermittency—the fact the sun isn't always shining—remains a challenge for utilities seeking to balance supply and demand across their wires 24 hours a day. So, some researchers are now looking to space where, despite its seeming infinite darkness, the sun is always shining. But transmitting that energy safely and efficiently to Earth is no small challenge.

That's why these investigators are studying ways solar energy could be transmitted wirelessly to Earth-based receivers, potentially providing access to 24/7 solar supplies. The actual implementation of this technology is likely decades off, but some governments and technology developers see the possibility of gigawatt-scale space-based power plants as soon as 2050. There is also the possibility of nearer-term use for similar power-beaming capabilities in terrestrial applications. These include

delivering power to remote locations without building out expensive transmission infrastructure.

There's no question that solar energy's contribution to U.S. electricity supplies has grown considerably over the last decade. In 2023, utility-scale solar comprised about 3.9% of the nation's total electricity capacity from utility-scale sources, according to the U.S. Energy Information Administration (EIA). And by 2025, the agency forecasts U.S. utility-scale solar capacity will grow by another 75%. But, with that growth comes a greater need to support demand during cloudy weather and overnight hours.

These limitations have scientists dusting off nearly 50-year-old research for ways to access solar resources that could act like baseload generators. This idea of capturing the sun's rays from space began as a possible commercial spinoff from NASA's space race, and attention grew during the 1970s oil crisis that followed. In fact, power-beaming records

achieved in 1975, when Raytheon and NASA used ground-to-ground beaming to send 34 kilowatts (kW) over 1.5 kilometers, have yet to be beaten.

The technology itself can sound a bit like a science fiction tale—and, in fact, J.D. Readle, an EPRI researcher studying this technology (which is called "directed energy" or "power beaming") says an Isaac Asimov short story, "Reason," published in 1941, has been an inspiration for his work in the field.

"A lot of my career so far has been in the field of directed energy—mostly for military uses, although there are a lot of other applications, as well," he said. "When the opportunity came up to get involved in helping this research, that was really exciting."

As Readle explained, the line diagram describing how space-based solar power (SBSP) would work is fairly simple and would begin with a photovoltaic (PV) solar array likely stationed in geosynchronous orbit, allowing it to remain aligned with an Earth-based receiving station. The DC power produced in the PV panels would be fed to a large transmitting antenna array that would convert the energy into microwaves and direct it to a receiving array, where it would be converted back to DC and then to AC power for delivery to the grid.

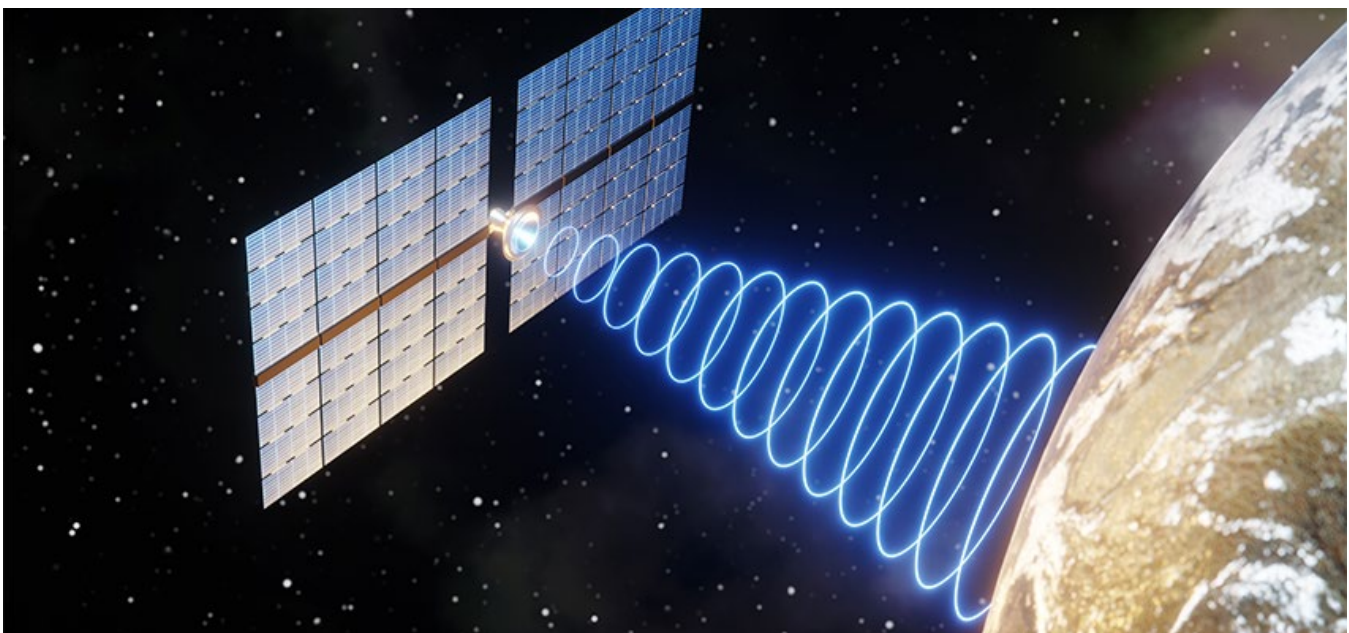
As imagined, though, there's a lot of complexity buried in this description, beginning with the cost of launching the space-based equipment into space,

especially given the size needed to generate the amount of power that would make the effort worthwhile. And the Earth-based receiving station also has significant size requirements.

"When we think about satellites, we might think about small satellites, taking the power in and converting it and sending it to where you need it," said Poorvi Patel, manager of strategic insight in EPRI's Technology Innovation program, noting that actual requirements are significantly larger. "It's not like five-by-five meters. It's more like kilometers that we're talking about."

### Many Research Threads

As Readle explained, the size requirements for both the space-based array and transmission system and the Earth-based rectifying antenna (or "rectenna") are driven by physics and the assumption that microwaves are the best choice for power transmission. "There are always tradeoffs—for example, you could have much smaller arrays if you use optical frequencies like lasers," he said. "But one of the things that makes it challenging to use laser wavelengths is they tend to lose more energy when propagating through the atmosphere, especially if it's rainy or cloudy. Microwaves can have lower atmospheric losses, so there are efficiency advantages, but they require much bigger apertures."



Readle said there is also more to be learned about the DC-to-microwave conversion process and the equipment used to facilitate that shift. Vacuum tubes—a technology as old as Asimov's short story—are currently favored in Earth-based applications, though solid-state sources have a potential for higher efficiency and much lower weight at a comparable power output. But, Readle said, solid-state options are still in development in terms of their ability to handle gigawatt-scale power transfers.

On the receiving side, Readle said, scientists have to relearn approaches that were first developed during the first exploration of SBSP's potential five decades ago, when the highest power-beaming and efficiency records were set. "There were various reasons for that, but one I thought was really fascinating, is that the antenna on Earth has relatively simple components, one of which is a Schottky diode that rectifies the microwaves to DC," he said, noting that the diodes originally used to realize high efficiencies at high power levels no longer exist. "So, they have to be redeveloped, and that's part of why it's hard to reproduce some of those previous records."

### Location, Location, Location

Of course, beyond the technology itself, there's also the challenge and cost of getting arrays and antennas up into space. Aiming for low-Earth (LEO) orbit, within 500-1,500 km, is the approach Elon Musk's Starlink internet service opted for, and it would be significantly less expensive than the planned geosynchronous approach. However, LEO satellites travel at a faster rate than the Earth's rotation, so maintaining uninterrupted power delivery could require multiple satellites and tricky handoffs. This is why research has focused on the geosynchronous approach, with fewer arrays that stay in close alignment with their terrestrial rectennas. However, those ground-based receivers may still need to have some of the same kind of tracking ability as today's utility-scale solar installations.

"For continuous 24/7 coverage, you would need to be in geosynchronous orbit with the ability to rotate the solar collectors sufficiently so you could always capture sunlight," Readle said, citing [a recent NASA](#)

[article](#). "There's another version of this where you're in the same orbit, but your collectors can't move as much. It could be a cheaper design, but it would be about 60% of the time that it could provide power."

Earth-based challenges include where to put the rectennas. As noted above, these installations need plenty of unobstructed space, defined by the physics of what would be necessary to receive the power gathered from solar arrays orbiting more than 22,000 miles above them. According to Readle, when considering the gigawatt-scale power required to make a project economical, this could translate to a site of up to 10 kilometers in diameter. This isn't out of alignment with some of the largest U.S. solar plants now operating. For example, the recently completed 800-megawatt Mount Signal Solar Plant in California's Imperial Valley spans 8 square kilometers.

### Where We Are Now

Researchers now have a big-picture understanding of how SBSP could operate and, Readle said, are diving into individual elements of that design. "I don't think anybody has been able to put it all together yet, and that's what I would love to see," he said, adding that besting the 1970s record of 54% DC-to-DC power efficiency at a greater distance would be a good start. "If someone could meet that over 1,000 meters, that would be really exciting."



Exploring power-beaming applications here on Earth could be a way to grow the technology as launching questions are addressed for more difficult space-based uses. These might include defense, using directed energy as a weapon. However, power beaming could also provide an alternative to wired transmission in rural locations. Emrod, a New Zealand-based startup, recently won funding from the German government to further develop its technology for transmission use. In 2022, the company demonstrated its ability to beam 550 watts of electricity 128 feet across a warehouse. The company suggests a possible future in which terrestrial solar and wind generators could beam their production to satellite receivers for redirection toward load centers without the need for transmission lines.

While EPRI has no active SBSP research projects underway, it is actively monitoring the technology's developments. For example, Readle has a white

paper in development outlining current understandings of the power-beaming aspects involved in bringing SBSP to reality, and EPRI has also released both a research prospectus and spotlight publication in the last year.

"As the technology starts to get more interest and into a commercialization type of phase, that's when the utilities will start to wonder, 'EPRI, can you look into it or do some demonstrations to evaluate the situation,' that's when we can do some more tangible research," said Patel, adding that today's growing need for additional carbon-free power makes SBSP a potentially important resource for the future. "We, as EPRI, need to be at the forefront and to see what's going on there."

### **EPRI Technical Expert**

J.D. Readle, Poorvi Patel



## How Collaborative Research Bolsters Utility Cyber Security

By Chris Warren

The FBI is worried. Over the past few months, the head of the U.S. Federal Bureau of Investigation, Christopher Wray, has [repeatedly](#) and very publicly sounded the alarm about the threat of cyberattacks on America’s most critical infrastructure, including the electric power system.

“The fact is, ...targeting of our critical infrastructure is both broad and unrelenting,” Wray [told](#) a gathering at Vanderbilt University in Nashville, Tennessee. Wray noted that advanced cyber threat actors’ motivations were varied, including economically motivated intellectual property theft.

The fact that a sophisticated nation-state would choose to launch near-continuous cyberattacks against critical infrastructure underlines something important: critical infrastructure, including the electric grid, is susceptible to cyber incursions and, equally important, needs stronger defenses against increasingly sophisticated attacks. Nation-states, criminals seeking payoffs, and terrorist organizations all view the electric grid as a prime target for cyberattacks.

What makes the grid such a tempting target for cyberattacks? Part of the answer lies in the fact that the grid is essential to everyday life, and any

disruption to its smooth operation can create havoc. However, the grid’s vulnerability to cyberattacks is also a function of its transformation to become far more decentralized and decarbonized. “We’re looking towards new ways of generating energy and assets working together more closely than they have in the past through IT (information technology) and OT (operational technology) integration,” said Jason Hollern, an EPRI Technical Executive for Digitalization. “It’s also about how complex the system is going to be and how integrated. That’s creating more security issues that need to be addressed.”

The vulnerabilities of the existing grid are also a function of its age. Indeed, many of the devices and equipment that keep the grid functioning have been operating for many decades and were not originally designed with security in mind. “They were designed and built for their function,” Hollern said. “The replacement of OT devices takes much longer than in IT, where it can be as fast as three to five years.”

Even when devices were designed with cyber security in mind, they often function using proprietary protocols—which can challenge both system cyber security and the necessary

interoperability a more distributed and digitized grid demands. Furthermore, those charged with maintaining robust cyber security are also in an inherently reactive position. “We learn of new threat capabilities of the adversaries on a day-to-day basis and constantly need to adjust and react,” Hollern said. “The goal is to have a less reactionary stance to cyber security and be more proactive.”

## Department of Energy (DOE) Backs Wide-Ranging Research

The growing threat of cyberattacks is no secret. EPRI has long been engaged in [research](#) to identify threats and develop tools and guidelines utilities can implement to prevent and effectively respond to attacks. Regulations and standards are also in place that require utilities and grid operators to take steps to defend against attackers. For example, bulk power system operators must comply with the North American Electric Reliability Corporation’s (NERC) Critical Infrastructure Protection (CIP) Standards focused on cyber security.

However, there is a clear understanding that much more needs to be done to adequately defend against the threat. To help accelerate the development of new tools and standards that can defend the changing electric power system, the U.S. Department of Energy (DOE) [announced](#) \$45 million in funding to support collaborative initiatives in six cyber security topic areas:

- Automated cyberattack prevention and mitigation
- Security and resiliency by design
- Authentication mechanisms for energy delivery systems
- Automated methods to discover and mitigate vulnerabilities
- Cyber security through advanced software solutions
- Integration of new concepts and technologies with existing infrastructure

This past March, the DOE’s Office of Cybersecurity, Energy Security, and Emergency Response selected EPRI to lead five projects aimed at reducing cyber risks facing the energy system. The EPRI-led projects span four of the DOE topic areas and include a wide range of partners, including member utilities like Salt

River Project (SRP), Southern Company, Consolidated Edison (ConEd), and Ameren, as well as universities like Virginia Tech and Penn State and technology companies like NVIDIA.

The projects also leverage EPRI’s past research and the use of EPRI’s laboratory in Knoxville, Tennessee, and Charlotte, North Carolina. “Each of these projects will use our internal lab capabilities to either do prototyping or proof of concepts,” Hollern said. “Each of them also has a demonstration component, where we implement new technologies in the field.”

While each of the projects will last between three and three-and-a-half years, EPRI will produce interim reports and host advisory meetings to provide updates and solicit feedback as it conducts its research. Another unique component of the projects is that they are focused on commercializing the technologies being developed. “The DOE wants to start moving the needle on getting these technologies out into utilities and into the industry,” Hollern said. “Each of them has a commercialization plan with identified commercialization partners so that a pathway to the industry can continue after the actual research is done.”

## Sampling of EPRI Projects

### Distributed Network Protocol (DNP3)

**Authentication and Authorization:** Over 90 percent of utilities in North America use cyber to monitor and control OT devices across their transmission and distribution systems. As more distributed energy resources (DER) like solar and energy storage are interconnected, the need for DNP3 to authenticate grid-connected devices increases significantly. Put another way, assets connecting to a more distributed and digitized grid need to communicate with a common and secure language.



Working with Salt River Project, EPRI will develop and test two communications standards: the Distributed Network Protocol Secure Authentication version 6 (DNP3-Sav6) and the Authorization Management Protocol (AMP). These will be built to authenticate and authorize devices using a zero-trust architecture.

“Zero-trust means that I can’t trust anything that’s talking to me until I have a way to understand that the person on the other side of the computer or the device talking to me is who they say they are,” Hollern said. “If they’re not, they could send me a bad command. They could steal my information. There’s a lot of bad things that can happen. Once you implement a zero-trust architecture that requires authentication and rules that apply to the different roles of devices and people, you significantly increase the entire network’s security.”

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**Hardware-Accelerated Security at the Edge (HASE),** Artificial intelligence (AI), and machine learning (ML) have enormous potential to reliably manage an increasingly complex, digitized, and distributed grid. The International Energy Agency (IEA) even [labeled](#) AI and energy “the new power couple,” partly because of AI’s capacity to unlock the flexibility needed to balance supply and demand when the grid has an abundance of variable wind and solar generation.

But AI also provides cybercriminals with an unprecedentedly powerful tool for exploiting vulnerabilities in a power system where so much is happening at the grid’s edge. “Now that we are decentralizing with the energy transition, there are going to be a lot more processes that are occurring by themselves at the device level on the grid edge,” Hollern said. “Providing visibility of that activity to



cyber defenders so they can respond to any event faster will be extremely important in this new energy environment.”

In the HASE project, EPRI is working with several partners, including Ameren, Southern Company, ConEd, Sygnia, Waterfall Security, Clemson University, and NVIDIA, to develop the next generation of advanced AI hardware to detect and stop cyber attacks. The project implements purpose-built Data Processing Units (DPU) to provide hardware security and replace traditional Network Interface Cards (NIC). The project will use NVIDIA’s hardware-accelerated DPUs to provide analytics and telemetry in industrial control system components used to control critical infrastructure processes. “The DPUs provide the communications on the network and have onboard capabilities to monitor the traffic locally at the device and detect when a cyberattack may be occurring on that network,” Hollern said.

The detection capabilities provided by the DPU are enhanced by AI, and responses to attacks can be automated or guided by security personnel. Indeed, AI capabilities can pinpoint when activities and processes are normal and when they may indicate an attack is underway. “The device can then take automated actions to start securing itself or hardening itself in real-time during an attack,” Hollern said. “Or it can recommend certain actions, and then a human can decide if they want to take those actions or not.”

For utilities like Missouri-based Ameren, a partner in the HASE project, the ability to enhance security with minimal disruption is especially appealing. “As a company that operates a wide range of critical infrastructure facilities, we need security detection solutions that are compatible with a wide range of OT equipment,” said Joseph Bradley, Senior Manager of OT Cyber Security for Ameren Digital. “The HASE project is an agentless solution that provides the same visibility and control as an agent but with minimal overhead and impact on the device. These approaches increase interoperability across a wide array of OT devices, from legacy PLCs to modern IoT sensors. Improving the cyber security capabilities of critical infrastructure environments without needing to rip and replace significant components will significantly improve our ability to adapt effectively.”

Southern Company is another utility partner in the project. Like Ameren, Southern Company is enthusiastic about how the research can provide more tools to defend the utility's assets. "As an operator of a large generating fleet, Southern Company is always looking for ways to improve the visibility and security of the OT network," said Charles Boohaker, Principal Engineer, Research and Development for Southern Company Services. "That's why I am excited about the proposed R&D project that aims to develop hardware-based offloading solutions that can integrate with the existing fleet and generate more actionable alerts."

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### **Digital Twins for Real-Time Cyber Attack Identification, Evaluation, and Mitigation**

Digital twins in the utility industry are generally thought of as tools that can improve the operations and maintenance of grid equipment or bolster the efficiency and reliability of an increasingly complex grid. Until recently, digital twins have not been thought of as a tool to enhance cyber security.

Over the past two years, EPRI has been exploring the potential benefits that can come from the traditional approach of modeling and analyzing security and operational data separately to instead combine that information into an integrated model. The Digital Twin project will build on those initial steps and seek to demonstrate its value using digital twins. More specifically, the project will explore the value of what EPRI terms hybrid digital twins.

"Hybrid digital twins model the physical assets, so we understand the actual processes occurring," Hollern said. "But then we also take live data or historical data from the historian and feed it into the model, and that's what makes it a hybrid." This approach can be extremely effective in improving cyber security because a hybrid digital twin can predict how a piece of grid equipment should perform based on certain inputs and determine how cyberattacks would impact the equipment.



Put more simply, a hybrid digital twin allows for comparisons that alert grid operators that a cyberattack is underway. "We can compare the actual performance of the asset to how the asset should be performing based on the digital twin," Hollern said. "If there is a threat actor that's attacking that physical system, there will be differences in the performance of that system compared to the digital twin. It is a mechanism to detect when a cyberattack could be occurring."

Hybrid digital twins do more than just detect when a cyberattack is underway. They also develop attack scenarios that anticipate the impact of an attack on a utility's physical systems. This is helpful information in constructing defenses and responses. "By developing the attack scenarios, we can start to characterize physical equipment impacts based on the type of attacks that could occur on that system," Hollern said. "By simulating those attacks on the digital twin, it'll give us a library of what to look for and what to expect. When those types of attacks actually occur, it won't be the first-time defenders will have seen them, and they can move more quickly to respond."

As the electric power system continues to evolve, so too will the threats against it. These collaborative projects will build on EPRI's long history of cyber security research and help develop the tools needed to ensure that a transformed electricity sector is safer, more reliable, and more resilient than ever before.

### **EPRI Technical Expert**

Jason Hollern





## **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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