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Why Data Readiness is One of Utilities' Most Urgent AI Challenges

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The Right Research at the Right Time

The first in a series of three articles about EPRI's long-term commitment to the Japanese nuclear industry post-Fukushima examines the days and weeks after the 2011 tsunami.

By Chris Warren

Even 15 years later, Rosa Yang still vividly recalls sitting in her Tokyo hotel room, with her shoes and jacket by her bed in case she needed to evacuate quickly. Yang was in Japan's capital one day after a tsunami triggered by the second most powerful earthquake ever recorded—the 9.0 magnitude Great East Japan earthquake—swept over Honshu Island, killing thousands of people and disabling three nuclear reactors at the Fukushima Daiichi power plant.

Just a day earlier, Yang had been thousands of miles away in her California home when she awoke on March 11, 2011, to news of the disaster. Whether it was fate or coincidence, Yang was scheduled to fly to Japan that same day to meet with some of the nation's top nuclear officials, her first trip as EPRI's new nuclear technical lead in Asia. Nobody would have protested if Yang had cancelled the long-planned trip. "With all the news, everybody told me not to go," recalled Yang, a nuclear fuels expert who spent over three decades at EPRI before retiring as the first-ever female EPRI fellow.

Yang ignored the warnings and got on a plane to Tokyo, where she could still feel the frequent aftershocks of the massive quake. Obviously, Yang's original itinerary to meet with a series of Japanese nuclear officials was scrapped. But she spent a week in Japan talking with people in the industry, including Shunichi Suzuki, the senior executive for Tokyo Electric Power Company's (TEPCO) research and development (R&D)—the owners of Fukushima—trying to figure out how EPRI could help.

THE VALUE OF BEING THERE

Yang's presence made a big impression on the Japanese nuclear industry. "They remember people who helped them," Yang said. "I can't tell you how many notes I've gotten from senior people saying you were here when everybody else left." Yang's initial visit to Japan in the days and hours after the devastating earthquake and tsunami expanded a deep and long-term partnership—one that continues to this day—between EPRI and the nation's nuclear industry.

Fukushima I Nuclear Power Plant
Photo courtesy the [Ministry of Land, Infrastructure, Transport and Tourism of Japan]

The first in a three-part series, this story will examine how Yang's initial trip kick-started several EPRI initiatives to help mitigate the immediate damage and to understand the events that led to the destruction of the three reactors. The following story will describe how EPRI helped ensure the reactors transitioned safely from active generation to a long period of layup, and how EPRI supported modernization efforts during that time. And the final story in the series will explore how EPRI has helped with reactor reopenings and life extension—work that has lessons for other nuclear power plants around the globe that are looking to operate longer than their original license periods.

In the aftermath of the tsunami, Japan shut down all 54 of its reactors to conduct safety reviews and establish new safety standards. The country also established the Nuclear Regulation Authority (NRA), an independent organization that assesses, reviews, and approves applications to restart reactor operations. A total of 15 reactors have restarted operations, including TEPCO's Kashiwazaki-Kariwa plant in early 2026.

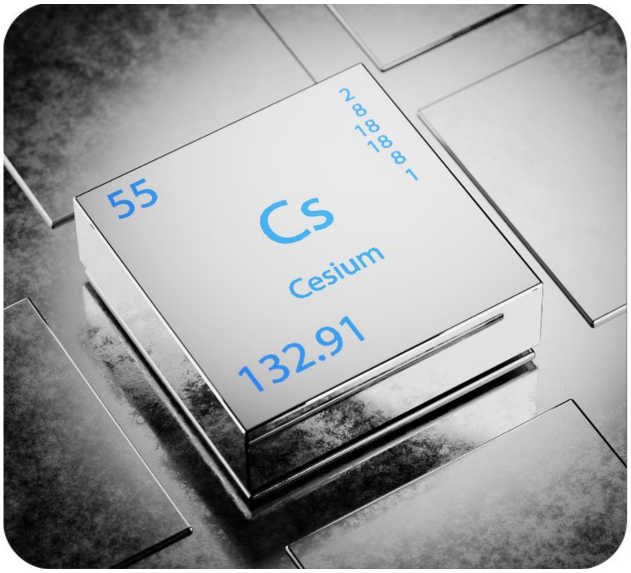
EPRI's post-Fukushima engagement with the Japanese nuclear power industry touched many aspects of the crisis and its aftermath. EPRI's depth of research on topics relevant to the challenges the nation's nuclear power plant operators faced after the disaster helped guide deeply consequential decisions in the immediate aftermath and in the years since. The value of that research will be discussed in this series.

While Yang acknowledges those specific benefits, she is also quick to emphasize the unique and wide-ranging value that EPRI delivered at a time when Japan needed it most. "The whole Fukushima story really underscores the unique value of who EPRI is and why EPRI is critical for the whole nuclear industry," Yang said. "Our collaborative model enables us to engage nuclear plant operators from around the world, build trust through our independence and objectivity, and then apply the best talent and best equipment to solve problems."

THE CESIUM CRISIS

Not long after Yang returned to the United States, she received an urgent call from TEPCO's R&D head, Suzuki. TEPCO faced a pressing problem. Radioactive fission products, primarily cesium, were contaminating the cooling water faster than TEPCO could store it.

Suzuki explained that TEPCO needed a way to remove the cesium before the rainy season flooded the reactor basements and transported the contaminated water into the ocean. As a nuclear fuels expert, Yang immediately acknowledged what she didn't know. "That's not my area of expertise," Yang thought. But Yang also remembered that a recently published EPRI technical report addressed exactly that problem.



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Quickly, Yang connected with EPRI's liquid waste processing and low-level waste management expert, Lisa Edwards, who had led the cesium removal research and served as program manager for radiation protection and low-level waste. Edwards recalls that EPRI members prompted the original research to analyze both the effectiveness of zeolites in removing highly radioactive cesium-137 from wastewater and the economics of their use.

Traditionally, resins are used to remove cesium-137 and other contaminants. Resins presented a critical problem at Fukushima, however: the site was saturated with salt water, both from the tsunami itself and from the emergency use of seawater as coolant when standard systems lost power. Saltwater renders resins ineffective. Zeolites, EPRI's research has demonstrated, have no such limitation.

Resins rely on ion exchange based on electromagnetic attraction. By contrast, zeolites create a small physical structure that captures cesium molecules. "Zeolites work like a key lock mechanism that cesium molecules fit in perfectly. Something else may get captured in the cage, but if a cesium molecule comes along, it will push it out," Edwards said. "It's highly efficient, and the report confirmed that. It really fit the bill in terms of the challenges TEPCO was facing at the time."

Shortly after a conference call with TEPCO, Edwards boarded a plane to Japan. She stayed for about 10 days and accompanied Suzuki to meetings evaluating potential solutions to wastewater contamination. It was an ideal role for EPRI. "We not only had recent research, but direct expertise that applied to their specific issues," Edwards recalled. "We could act as their technical expert to evaluate different options, and they knew that we were coming at it without any vested interest. Our only agenda was their success, and they knew that."

Edwards' practical experience with radioactive waste processing also informed specific engineering recommendations. In normal nuclear plant operations, vessels containing spent removal media are periodically emptied by sluicing the radioactive material out into a separate container for disposal. At Fukushima, however, the cesium concentrations were so high that the spent zeolite inside each vessel would be intensely radioactive after capturing it. Edwards advised TEPCO to treat each vessel as its own disposal container—meaning that when a vessel was exhausted, workers could remotely disconnect and remove the entire unit and replace it with a fresh one, rather than attempting to move the highly radioactive material inside. This eliminated the risk of spills, clogs, or equipment failures while transferring material that, given the radiation levels involved, nobody could safely approach.

Beyond its expertise and research knowledge, EPRI also applied its extensive global network to identify the right solution provider to support TEPCO. Through her extensive work in the industry, Edwards was well acquainted with Kurion, a company that owned the patent for the cesium-specific zeolite (the same zeolite used during the Three Mile Island clean-up) TEPCO needed. Not only did Edwards, Yang, and EPRI's country manager, Michio Matsuda, connect TEPCO and Kurion, EPRI also helped design the specific treatment approach used at Fukushima and helped kick-start the project. "We were able to survey the whole world to find the best people to do the work," Yang said. "Very few companies have that kind of reach." Recommending both a specific technology and a specific vendor was unusual for EPRI, but Yang felt the emergency justified the exception.

Kurion's work with TEPCO was an enormous success. Over just a few months, before the rainy season began, Kurion removed more than 99.9 percent of the cesium, preventing significant ocean contamination.

READING THE BLACK BOX

EPRI also helped TEPCO clarify the chain of events at Fukushima. Within hours of the accident, Fukushima lost all power, eliminating any possibility of collecting plant data. "Reconstructing what happened without that data was like trying to recreate a plane crash without a flight recorder," Yang said.

EPRI turned to its Modular Accident Analysis Program (MAAP) to begin filling in those knowledge gaps—information that was needed to guide the immediate response and to inform future regulations and guidelines to enhance safety. Originally developed after the Three Mile Island accident in 1979, MAAP is a computer simulation tool that models the progression of events during a severe nuclear accident. MAAP is especially helpful for guiding decisions and actions during a crisis because it can run simulations faster than accidents unfold.

Because there was limited plant data from the critical early hours of the accident, EPRI used MAAP to help TEPCO understand what could be happening inside the damaged reactors, including the likely sequence of events and available response options. As new information emerged—such as equipment conditions, water injection volumes, and timing—EPRI updated its MAAP models to sharpen the picture.

MAAP helped estimate when the cores at Fukushima overheated and melted, when they reached the bottom of the reactor pressure vessel, and how much core material likely reached lower regions of the plant. MAAP simulations helped develop scenarios for the expected condition and approximate location of the core debris, which is vital information for safe response and recovery activities.

The insights MAAP generated had consequences far beyond Fukushima itself. EPRI used those findings to update the technical basis for Severe Accident Management Guidelines—the detailed emergency playbooks that nuclear plant operators worldwide consult when responding to a crisis. The updated guidelines addressed scenarios such as the extended power outages experienced at Fukushima, providing an improved resource that the global industry can use.

Fukushima also directly transformed MAAP's future. The event revealed the need for enhanced capabilities in the MAAP code. The Japanese government stepped in to support the enhancements with several million dollars in funding, ensuring the tool that helped manage one accident would be far better equipped to help prevent or manage the next one.

Nearly all U.S. nuclear utilities use MAAP analyses to develop portable equipment plans—detailing how to deploy backup pumps and power supplies when permanent systems fail—that they submit to regulators. MAAP's reach has grown substantially

Fukushima Daiichi
Photo Credit: Susanna Loof / IAEA

since Fukushima. Today, the software is used worldwide, and Japan's nuclear utilities rely on it to evaluate plant safety as they seek government approval to restart their reactors. "All nuclear plants worldwide are safer today than before March 2011 because of all the lessons we have learned from Fukushima," Yang said.

THE HUMAN TOLL

The safety improvements MAAP helped drive were significant. Still, Yang believes EPRI's most lasting contribution from those chaotic weeks was something harder to quantify—captured perhaps best in something Michio Matsuda, EPRI's country manager, told her bluntly before the accident: nobody in Japan knows who EPRI is.

That changed dramatically after Fukushima, as EPRI's role in supporting Japan's nuclear industry spread quickly across the region. Before the accident, only two of Japan's utilities—TEPCO and Chubu—were full EPRI members. Today, all but one of the nation's 11 nuclear utilities have joined as full EPRI members. Even with all nuclear plants shut down and revenues severely strained, Japanese utilities continued to fund EPRI research programs—a demonstration, Yang believes, that the relationship had grown into something beyond a typical commercial arrangement. Awareness of EPRI also expanded across Asia, and Yang found herself being asked about what EPRI had done to help while visiting places like Korea and China.

A few years after the accident, Yang was also asked to serve on the International Expert Group (IEG), a global group of nuclear professionals formed to support the cleanup at Fukushima. "I told them I'm not a decommissioning expert, I'm a nuclear fuels expert," Yang said. "But they said, 'You have our best interest in mind. You are a friend; we want you on the committee.'"

Despite the decade and a half that has passed since the hectic and chaotic days after the accident, both Yang and Edwards have vivid memories of what it was like to be in Japan at the time. Edwards remembers being in a large conference room with 30 to 40 engineers whom TEPCO's Suzuki had gathered to figure out how to accelerate radioactive waste cleanup. The discussions were deeply technical and intense, driven by an urgency to solve problems.

In the middle of a presentation, Suzuki stood up and said it was time to observe a moment of silence to mark the anniversary of the tsunami. Edwards had been absorbed in the technical discussion, looking down at her notes. "We had been working together, and it had all been very technical, and everyone had been very stoic," Edwards said. "I looked up, and many of the faces were still stoic, but I could see tears rolling down their cheeks. In that moment, the enormous emotional toll these people were laboring under, and how many of them had lost friends and family to the tsunami or didn't know their status, really hit me. It was a defining moment that has never left me."

EPRI TECHNICAL EXPERTS

Lisa Edwards and Rosa Yang

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How Electrification Could Save Households Thousands Despite Rising Electric Bills

By Chris Warren

Few topics garner as much attention and debate these days as energy affordability. For instance, rising energy prices, especially electric utility rates, catapulted to the forefront of the 2025 gubernatorial elections in Virginia and New Jersey. Researchers, regulators, and policymakers are all grappling to ensure all customers have access to affordable electricity.

While energy affordability has become a topic of understandable interest and action—connected closely to broader discussions about inflation—many people lack clarity about the primary drivers of energy costs. Also, little is understood about how energy costs may change as electricity takes on a more prominent role in powering transportation, heating and cooling buildings, and an increasing number of industrial uses.

Many people think of their electricity bill when they assess their household energy costs. But for the average U.S. household, gasoline is the single largest energy expense—a fact that often surprises people because fuel purchases don't arrive as a monthly bill.

Clarifying the full picture of household spending across all energy sources—and how it is affected by increasing electrification—was the focus of the August 2025 white paper, *The Energy Wallet: U.S. and State-Level Household Energy Expenditures, Past and Future*.

A clear understanding of how electricity's contribution to household energy costs compares to other energy types, and how it is changing with greater electrification, matters for utilities as they plan to meet load growth, communicate the value of electrification for their customers, develop and operate customer programs to ensure affordability, and consider rate designs and incentives to contain costs.

A COMPREHENSIVE VIEW OF ENERGY SPENDING

EPRI's Energy Wallet analysis uses data from the U.S. Energy Information Administration (EIA) State Energy Database System and other sources to quantify what households in all 50 states spend on all sources of energy, including electricity, natural gas, heating fuels, gasoline, public charging for electric vehicles (EVs), and the amortized cost of residential solar.

The report provides a historical view of this basket of average household energy expenses, presents them in both nominal and inflation-adjusted terms, and accounts for population growth. EPRI compiled future projections through 2050 using its US-REGEN energy systems model, which analyzed scenarios with and without continued implementation of the Inflation Reduction Act (IRA) policies and varying fuel prices. In both scenarios, consumers adopt EVs and heat pumps based on their cost advantage over conventional alternatives. The results point to a perhaps counterintuitive conclusion: as electrification expands, total household energy costs are likely to fall significantly, even as electricity bills increase.

Main takeaways about current energy spending included:

- Average Energy Wallet spending—meaning direct annual spending on all energy sources—in the U.S. in 2024 was $5,530 per household. States differed significantly in their average household energy expenditures, with New England states and Alaska spending the most (Maine topped the list at approximately $7,800) and Utah coming in lowest at about $4,400.
- On average, U.S. homes spent the most on gasoline, at nearly $3,000 per household, while average electricity expenses were $1,850. In every state, electricity expenses accounted for less than half of all Energy Wallet spending.
- Adjusting for economy-wide inflation, the average U.S. Energy Wallet in 2024 was almost identical to what it was in 2020. Over nearly two and a half decades, Energy Wallet spending fluctuated considerably. During the COVID-19 pandemic in 2020, when people commuted much less because of lockdowns, the U.S. average was $4,590. Elevated fossil fuel prices in 2008 drove average Energy Wallet spending to nearly $8,000. There was much less fluctuation in electricity spending over the same period, with average household utility bills ranging from $1,600 to $2,000.

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- While the average U.S. residential electricity price increased 30 percent in nominal terms between 2020 and 2024, the price adjusted for economy-wide inflation rose by only 5 percent.

THE ELECTRIFICATION ADVANTAGE

Pinpointing the elements that constitute the Energy Wallet and examining historic trends provides helpful clarity into household energy expenditures. For utilities, what is arguably more important is to understand how household energy expenditures may change in the future, especially as electrification gains momentum.

The report offers potentially good news for the affordability of household energy expenses. Depending on the policy environment and fuel prices, if consumers adopt EVs and other electric technologies, like heat pumps, at the rates suggested by their cost advantages, the average U.S. household Energy Wallet could fall in real terms by 36 to 42 percent by 2050, with state-level declines ranging from 10 to 55 percent.

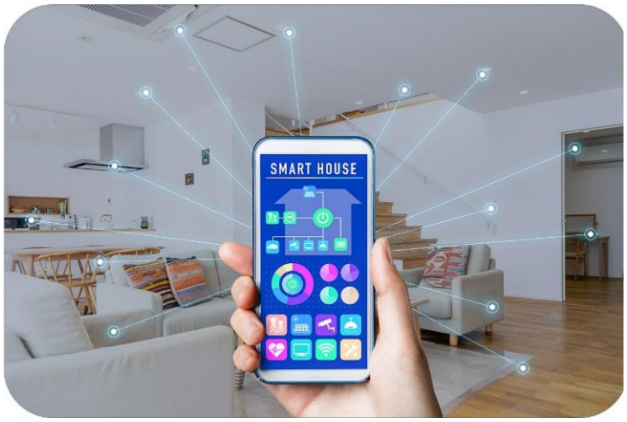
Simply put, greater electrification has the potential to significantly improve household-level energy affordability. The main driver of the savings is the shift from gas-powered vehicles to EVs; the final energy consumed per mile by a light-duty EV is about a third that of a comparable internal combustion engine vehicle. “The decline in the

Energy Wallet is driven primarily by replacing gasoline expenditures with increased spending on electricity as personal vehicles are electrified," said Geoffrey Blanford, an EPRI principal technical executive, who co-authored the report with Chris Roney, senior team lead in the Energy Systems and Climate Analysis Group at EPRI. Building electrification, including the proliferation of heat pumps and improved appliance energy efficiency, also contributes to lower household energy expenses.

While lower overall energy costs would undoubtedly be welcomed by households, increased electrification is also likely to increase scrutiny on utility bills. "As you electrify a home, people are going to spend more on electricity, both in nominal and inflation-adjusted real dollars," Roney said. "They're going to spend a lot less on their energy bill, but it's going to have the secondary effect of increasing the prominence of electricity bills in home energy economics."

TURNING INSIGHT INTO ACTION

The dynamics of falling overall household energy costs, fueled by increased electrification, combined with rising utility bills, are ones that utilities and customers need to grasp fully. Indeed, the data and modeling in the report can help inform utility communication and education efforts targeted at regulators, policymakers, and consumers around what increased electrification means for individual customers. This takeaway might not be immediately obvious to customers concerned about rising electricity bills.



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The full picture provided by the Energy Wallet equips utilities with tools to more effectively address affordability concerns. "The electrification trend drives down household expenditures, even though you're increasing your electricity bill," Blanford said.

"That's such an important message for utilities to be able to share with their customers." Insights from the Energy Wallet research provide data points to help frame rising electricity prices within the context of falling total energy costs.

The research can also support utility designers of customer electrification programs. Clarity about which households stand to save the most from electrification can help inform how to target incentives and assistance programs to households that will benefit financially.

The insights have immediate value in addressing growing concerns about the impact of data centers on electricity prices. "There's a widespread fear that if electricity has to do more, including powering data centers, then affordability is going to get worse and worse," Roney said. "But the evidence points in the other direction. EPRI's [Win-Win Watts] research has shown that new electricity demand has historically tended to lower rates on average, and what the Energy Wallet research shows is that there are a ton of possible savings for households because of greater electrification."

The Energy Wallet analysis presents state-level averages, which provide valuable insight but don't capture the wide variation in energy spending across different household types. A family with multiple vehicles and long commutes, for example, will have higher energy costs than a household that drives little. When analyzed alongside income data, these variations become critical for understanding energy burden—the share of household income spent on energy—particularly for vulnerable populations.

EPRI is launching supplemental research to address these questions through collaborative case studies with participating utilities. Utilities can still participate in the follow-on work, which will focus Energy Wallet findings on utility service territories and examine distributional impacts across different household types. "We want to understand the factors that are going to change an individual household's spending profile and how much money they might stand to save in an energy transition towards more electrification," Roney said. This granular analysis will help utilities design programs to meet both today's needs and anticipate how those needs will evolve as electrification accelerates over the next few decades.

As households electrify their vehicles and homes, the electricity bill will likely become the most visible measure of what Americans spend on energy. “Utilities need to prepare for what that means,” Roney said. “Communicating the financial benefits of greater electrification means helping customers understand that a higher electricity bill can mean lower overall energy costs.”

EPRI TECHNICAL EXPERT

Geoffrey Blanford and Chris Roney

EPRI JOURNAL

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Why Data Readiness is One of Utilities' Most Urgent AI Challenges

Realizing AI potential starts with getting data right.

By Chris Warren

In a relatively short period of time, artificial intelligence (AI) has become the centerpiece of discussions across most industries, including the utility industry. Much of the recent focus has been on utilities' ability to meet the growing demand for electricity coming from data centers powering AI applications. In August 2025, for example, EPRI and Epoch AI released a report forecasting that the total AI power demand in the U.S. could grow from 5 GW at the time of publication to more than 50 GW by 2030.

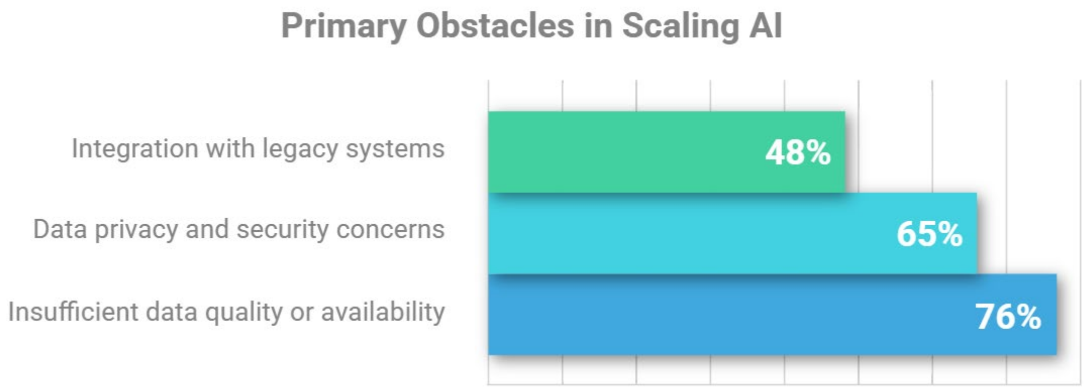
Meeting the electricity demand from these large new customers is understandably a top utility priority.

But utilities are equally motivated to leverage AI to improve everything from their operations and maintenance (O&M) to their planning and investment decisions. In March of 2025, EPRI joined with national labs, universities, utilities such as Duke Energy and Exelon, and technology firms such as NVIDIA, AWS, and Microsoft to launch the Open Power AI Consortium.

"The mission of the Open Power AI Consortium is to transform the electric sector by leveraging AI, as appropriate, to improve how electricity is made, moved, and used," said Jeremy Renshaw, director of the Open Power AI Consortium. "We need to utilize the members of the consortium to think big and push the boundaries of what is possible as well as help to inform regulators and policymakers by bringing them closer to the development process."

THE FOUNDATION OF AI

There is a dizzying array of already feasible and emerging applications of AI in the power sector. EPRI is pursuing an ambitious AI research agenda, exploring everything from how it can improve wildfire detection, grid management, predictive maintenance, and cybersecurity across hundreds of use cases in the utility industry.



It is already clear that AI's ability to help prevent outages, accelerate wildfire response, and manage an increasingly complex grid comes down to data.

A survey of Open Power AI Consortium members found that data readiness, or lack of it, is a primary obstacle in scaling AI. Indeed, 76 percent of survey respondents cited insufficient data quality or availability as a top barrier; 65 percent highlighted data privacy and security concerns; and 48 percent noted challenges around integration with legacy systems.

The report *AI Readiness in Utilities: Turning Data into Strategic Advantage* was released in August 2025 and validates the critical importance of data readiness in transforming AI potential into value, and it provides a five-point framework to achieve it. Developed with input from the utilities Constellation Energy and PPL and the consulting companies Accenture, PwC, and EY, the report defines data readiness as a scalable data architecture that provides clean, structured, and governed data, enabling advanced AI models to achieve specific business outcomes.

Put simply, data readiness is foundational to tap the potential of AI to improve grid resilience, customer engagement, forecasting, and to manage and orchestrate an increasingly distributed grid. "When our clients ask for help with their AI strategy, our first question is: what is your data strategy?" said Mike Juchno, a principal and consulting partner in EY's data and AI energy sector practice.

Currently, most utilities do not yet have the level of data readiness needed to fully realize AI's value. Common challenges include limited data accessibility across the enterprise, unresolved privacy and security concerns, and inconsistent data quality.

"It's well-known in the industry that many utility data sources, including GIS (geographical information systems), are not 100 percent accurate," said Matt Wakefield, EPRI's director of Information Communication and Cyber Security (ICCS) and one of the co-authors of the report. "The real question is whether AI can still support sound business decisions when data is incomplete or inconsistent. In our experience, it can but only happen when utilities understand those limitations and design AI use cases accordingly."

A ROADMAP TO DATA READINESS

Achieving data readiness doesn't just occur naturally. It requires direction, leadership, and a commitment to continuous improvement. EPRI and its collaborators in this research developed a five-step framework to secure the data readiness needed to drive AI benefits and scale. The five steps are:

- **Secure executive ownership.** Data readiness must be treated as a utility-wide strategic priority, with clear executive accountability for data strategy, governance, and investment decisions. Without clear C-suite alignment and support, individual business units may pursue their own data-readiness strategies, leading to duplication of effort and inflated costs. "Data needs to be used across the organization for AI. If there is a framework for data readiness in one business unit that is different in other business units, there's a lack of efficiency, and you miss the force multiplier effect," Wakefield said. "Having a top-down strategy helps the entire organization."

- **Build a strategy that connects data to business outcomes.** Data readiness is ultimately defined by the specific business outcomes utilities want AI to support. Clarity on what those outcomes are makes the steps towards data readiness more targeted and efficient. This includes defining how data supports measurable business outcomes; ensuring data is well-documented and traceable; and identifying any data gaps that need to be closed.
- **Build a data culture.** Data has always been important to utility operations and decision-making. But AI has dramatically raised the stakes, demanding that utilities evolve accordingly. "Part of this is recognizing that data is an asset, just like physical assets," Wakefield said. "When data is truly an asset, you need to be able to leverage it as an asset by ensuring it is accurate, accessible, and governed. Building a data culture means having the processes and mindset to do that." Building a data culture requires continuous education about data literacy and fostering a collective understanding about the connection between data and the business outcomes utilities want to achieve.
- **Demonstrate value with targeted use cases.** Though the applications of AI are potentially transformative, their implementation demands significant change. Building the tools, processes, knowledge, and commitment for that change requires early successes. Starting with small use cases that deliver quick and tangible value builds internal support. "We selected use cases with high business value and manageable data complexity to demonstrate early success and build momentum," said John Brady, senior manager for IT at Constellation Energy. For example, one use case is to leverage AI to evaluate drone imagery of transmission and distribution infrastructure. Properly trained AI can trigger predictive maintenance that repairs or replaces equipment before it fails. But those wins only build momentum if utilities actively communicate them across the organization.
- **Learn, scale, and institutionalize.** Data readiness is not a task that can be completed quickly. It takes time, flexibility, and continuous learning. As deployments occur, utilities should capture and share any lessons learned and develop best practices to guide future initiatives around data readiness and data governance. Over time, this builds on existing data governance and management practices, increasing maturity and confidence and making it more likely that AI consistently delivers the outcomes utilities seek.

COLLABORATION IS AN AI CATALYST

Ultimately, the steps necessary to become AI data-ready must take place within utilities. But collaboration among utilities, technology providers, academics, national laboratories, and others can accelerate progress for everyone.

The Open Power AI Consortium provides many opportunities for collaboration, including:

- Launching pilot projects and co-innovation via AI sandboxes
- Gathering input from industry surveys on the most valuable use cases to undertake. Utilities and technology providers can share their insights in one of the two following survey links:
  - Utility survey: https://www.surveymonkey.com/r/OPAI-Use-Cases-Utilities
  - Technology provider survey: https://www.surveymonkey.com/r/OPAI-USe-Cases-Tech-Providers
- Establishing working groups on specific topics. To date, four working groups have been launched (see www.openpowerai.org for more information on how to engage)
- Applying shared data standards and interoperability frameworks for data exchange across systems
- Building industry-specific datasets, knowledge graphs, and foundation models
- Investing in AI literacy and workforce reskilling

EPRI has already worked with consortium members to identify open-source datasets and AI models, and has published white papers on how to prepare data to be AI-ready; these are all available on the Open Power AI Consortium website. In addition, EPRI surveyed consortium members and presented findings about over 250 AI use cases across the power sector.

Future consortium goals include expanding its global membership, developing new iterations of power industry-specific AI models, and evaluating high-priority use cases identified in the survey. “We plan to scale deployments, host global and regional AI workshops, formalize partnerships with academia and national labs, and maintain AI sandboxes with technology companies for collaborative experimentation and co-innovation,” Renshaw said. “These efforts collectively aim to establish the consortium as the global hub for AI in the power sector.”

EPRI TECHNICAL EXPERTS

Matt Wakefield and Jeremy Renshaw

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Synthetic Customer Load Data: Approaches, Limitations, and the Role of Generative AI

By Chris Warren

Electric utilities are navigating a period of rapid change driven by electrification, renewable energy integration, climate variability, and evolving customer behavior. These trends are placing new demands on planning processes that have historically relied on empirical load data, such as advanced metering infrastructure (AMI) records or curated reference datasets. While these data sources remain valuable, they are constrained by privacy considerations, incomplete coverage, limited historical depth, and a limited ability to represent emerging technologies or future scenarios. Against this backdrop, synthetic customer load data has emerged as a complementary tool for utility planning and analysis.

Synthetic customer load data refers to artificially generated datasets designed to replicate the statistical, temporal, and spatial characteristics of real electricity consumption. Rather than representing actual customers, these datasets emulate patterns such as daily and seasonal demand, household diversity, and responses to technology adoption and weather conditions. When developed using appropriate safeguards, synthetic data can be shared and analyzed without exposing personally identifiable information, addressing one of the most persistent challenges associated with AMI data. The research examines two primary approaches to generating synthetic customer load data—simulation-based models and generative AI-based models—and evaluates their benefits, limitations, and potential roles in utility planning.

MOTIVATION FOR SYNTHETIC LOAD DATA

Utilities face several structural limitations when relying solely on empirical AMI datasets. Privacy concerns often require restrictive data governance policies and, in some cases, explicit customer consent for data sharing, adding cost and complexity to collaboration with third parties. AMI deployment, while widespread, remains uneven, and even mature systems typically offer less than a decade of historical data. In addition, customers who opt in to data sharing may not be representative of the broader population, introducing potential biases into planning studies. Managing AMI data also imposes a significant computational and financial burden, as utilities must store, secure, curate, and process large volumes of high-resolution time-series data.

Synthetic data tools help address these challenges by reducing dependence on sensitive customer records and enabling scalable, flexible scenario analysis. Once developed and benchmarked, synthetic datasets can be generated quickly, labeled consistently, and adapted to evaluate future technology, policy, and climate scenarios that are not yet reflected in historical data. As a result, synthetic load data allows planners to focus more on analysis and decision-making rather than data acquisition and management.

UTILITY AND CUSTOMER USE CASES

The applications of synthetic customer load data extend beyond traditional forecasting and resource planning. Synthetic datasets can be used to augment sparse or anonymized AMI records, filling gaps in temporal, geographic, or behavioral detail. They support modeling of emerging technologies, such as electric vehicles, heat pumps, and distributed solar, enabling utilities to assess adoption pathways and design forward-looking programs. Synthetic data is also valuable for grid resilience and extreme-event analysis, allowing planners to test system performance under severe weather or high-load conditions.

On the customer side, synthetic data can underpin energy audits, diagnostics, and advanced analytics tools without relying on sensitive usage records. It can support personalized tariff comparisons and efficiency insights while preserving privacy. In addition, synthetic datasets facilitate collaboration among utilities, regulators, and researchers by providing a common, shareable resource, and they can be used in education and workforce development to build expertise in energy analytics and grid planning.

SIMULATION-BASED APPROACHES

Simulation-based models generate synthetic load data using physics-based representations of building energy consumption rather than historical usage records. These models replicate demand by combining information on building characteristics, occupancy patterns, appliance specifications, and environmental conditions such as temperature and solar radiation. Grounded in thermodynamics and related physical principles, simulation-based tools produce profiles that reflect realistic temporal and spatial variability.

A key strength of this approach is its maturity. Many physics-based simulation tools are commercially available, well validated against empirical benchmarks, and capable of representing a wide range of technologies and climates. They are particularly well-suited for long-term infrastructure planning, distributed energy resource integration, and climate scenario analysis. Simulation-based models also offer transparency and explainability, as results can be traced directly to the defined assumptions about end uses, customer behavior, and environmental inputs.

However, these strengths are balanced by notable limitations. Simulation-based tools often require specialized expertise to define and calibrate assumptions about building stock, occupant behavior, and regional practices. At scale, they can be computationally intensive, with large simulations taking hours or days to complete, which can limit their suitability for iterative or real-time applications. In addition, empirical benchmarking remains necessary to establish credibility, adding to the technical burden of implementation.

GENERATIVE AI-BASED APPROACHES

Generative AI-based models take a fundamentally different approach by learning directly from high-resolution empirical data, such as AMI records. Using machine learning architectures, these models capture the statistical distributions, temporal patterns, and correlations present in real consumption data and use them to generate new, synthetic load profiles. The resulting datasets preserve key characteristics of observed behavior without being tied to any specific customer.

Generative AI models can rapidly produce thousands of diverse load profiles once trained, making them computationally efficient at scale. They are particularly effective at capturing complex behavioral dynamics and implicit relationships between customer attributes, time, and consumption patterns that are difficult to model explicitly. With appropriate privacy safeguards, such as differential privacy, these models can mitigate the risk of exposing individual customer information while maintaining statistical fidelity.

At the same time, generative AI remains an emerging area for utility applications. Model performance depends heavily on the quality, completeness, and labeling of training data, and poorly curated datasets can lead to biased or unrealistic outputs. Standardized frameworks and regulatory guidance are still evolving, and many planners lack experience calibrating AI models to reflect local system characteristics. Generative models also struggle to reproduce rare or extreme events unless those conditions are well represented in the training data, highlighting the need for careful benchmarking and ongoing refinement.

CASE STUDY: INSIGHTS FROM THE FARADAY MODEL

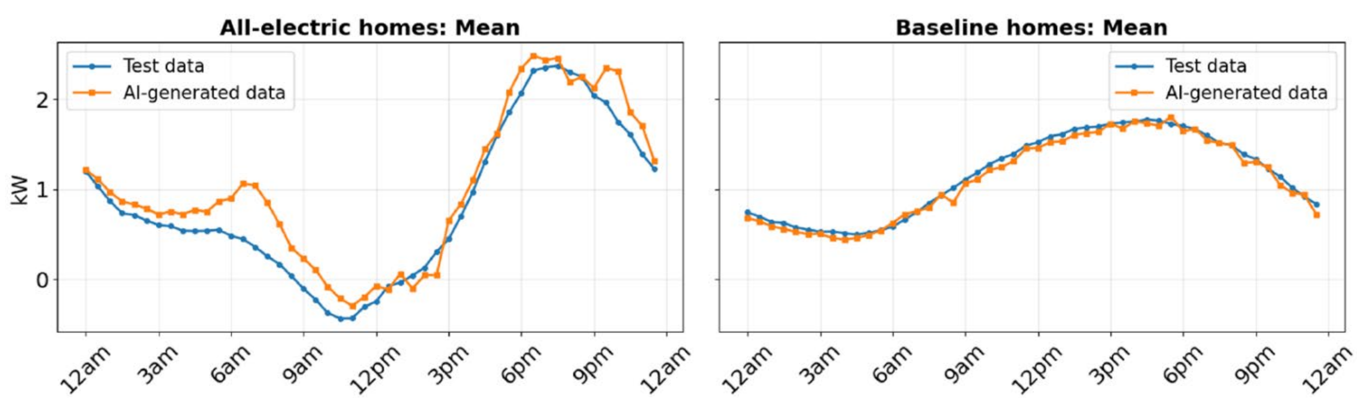
To explore the applicability of generative AI for generating synthetic customer load data, the paper presents a case study using the Faraday model developed by the Centre for Net Zero. Faraday employs a customized variational autoencoder architecture designed to capture the positively skewed distribution of residential electricity demand, including infrequent high-load events. For this study, Faraday was trained on simulated U.S. residential load data generated with EPRI's LoadSim tool, which provided a proxy for large volumes of labeled AMI data.

The study modeled 2,000 single-family homes in Knoxville, Tennessee, split evenly between all-electric and baseline fossil-fueled configurations. After training, the model generated thousands of synthetic daily load profiles in under a minute. Comparisons between synthetic and holdout test data showed that Faraday could reproduce key characteristics of residential demand, including differences across technology configurations, the impact of rooftop solar, and electric vehicle charging behavior. While overall fidelity was reasonable, the analysis also highlighted limitations related to extreme events, unobserved technology combinations, and the inability to capture multi-day dynamics when profiles are generated independently.

- Synthetic Load Data
- Generative AI
- Simulation-Based Models

SUMMARY AND OUTLOOK

Synthetic customer load data offers utilities a flexible, privacy-preserving complement to traditional AMI datasets. Simulation-based and generative AI-based approaches each provide distinct advantages and face distinct limitations. Simulation-based models offer transparency, physical grounding, and strong performance in long-term and climate-focused analyses, but they can be computationally intensive and require specialized expertise. Generative AI models provide speed, scalability, and the ability to capture complex behavioral patterns. Still, they depend on high-quality training data and face challenges in modeling extremes and unobserved scenarios.



Faraday generated profiles vs. test data (mean kW, summer/weekend)

The intended application should guide the choice between approaches, and hybrid methods combining physics-based simulations with generative AI may offer a promising path forward. By strengthening benchmarking efforts, establishing common standards, and piloting real-world implementations, utilities can build confidence in synthetic datasets. Over time, these tools can support more informed decision-making, enhance collaboration, and help the energy sector prepare for an increasingly complex and uncertain future.

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.

EPRI JOURNAL

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Beyond Billing: How Utilities Can Unlock the Full Value of Advanced Metering Infrastructure

By Chris Warren

Judging by the numbers alone, the rollout of advanced metering infrastructure (AMI) has been an undeniable success.

Utilities such as Pacific Gas & Electric (PG&E) and Florida Power & Light (FP&L) were among the first to launch ambitious smart meter deployments in the mid- to late 2000s. It was the beginning of a shift away from analog meters, quickly and enthusiastically followed by utilities across America—and accelerated by billions in grid modernization funding from the American Recovery and Reinvestment Act (ARRA) in 2009.

Today, it's more likely that homes and businesses have smart meters than don't. A recent report by the Federal Energy Regulatory Commission (FERC) found that nearly 77 percent of all meters across residential, commercial, and industrial customers are now AMI, totaling nearly 130 million meters.

It's understandable why utilities have been so eager to embrace AMI. Smart meters that can transmit consumption data eliminate the need for manual meter reads, saving operational costs and reducing truck rolls. Smart meter deployments have also delivered on other early promises, including improved billing accuracy and quicker outage detection, which accelerate restoration efforts.

While these operational gains have been real, many of the transformative promises of AMI have gone largely unrealized. In fact, despite billions invested and near-universal deployment of smart meters, a recent EPRI survey found that more than 60 percent of utilities are still primarily using their smart meters for billing and outage alerts. These uses deliver genuine value, but they are not nearly as transformative as some of the early promises of dramatic reduction in peak demand, robust customer engagement, and dynamic pricing.

That gap is prompting hard questions, especially now that many of the original smart meters are approaching the end of life and utilities are considering whether to invest in new AMI systems. "We are seeing this next generation of metering systems, call it AMI 2.0, that include some really advanced capabilities," said Matt Wakefield, EPRI's director of Information Communication and Cyber Security (ICCS). "Utilities are asking whether it's worth investing in this next generation of AMI and, if so, how to actually unlock its value. That means addressing integration, interoperability, and organizational alignment, not just buying better meters."

> *60% of utilities expect to upgrade their AMI systems within the next five years*

THE VALUE GAP

EPRI recently launched the three-year initiative, NextWave AMI: Unlocking the Full Value of AMI, to drive industry collaboration and answer these hard questions, helping utilities achieve the full potential of smart meters. To guide the project's research agenda and priorities, it began by surveying 99 global utilities and technology providers. The survey sought to understand how utilities are using AMI today, what challenges prevent them from doing more, and the future capabilities and use cases they prioritize.

The survey results underscored the basic insight behind the initiative, that utilities face an inflection point and are determined to fully leverage the capabilities of smart meters. For example, over 60 percent of utilities expect to upgrade their AMI systems within the next five years. Given that AMI deployments cost hundreds of millions, even billions, a clear understanding of what prevented the most transformative smart meter capabilities from becoming a reality is necessary.

TECHNICAL AND INSTITUTIONAL BARRIERS

The survey found that some of the obstacles are well-known technical challenges. The most frequently cited constraint preventing utilities from tapping the full value of existing smart meters was limited integration with other utility systems, including distribution management systems (DMS), outage management systems (OMS), and geographic information systems (GIS). Another technical challenge limiting the impact of smart meters was the lack of real-time data access, cited by 43 percent of utilities. This is the result of AMI systems being designed to transmit data once or just a few times a day, which is adequate for billing but not nearly as frequent as needed to manage a complex grid.

The obstacles preventing utilities from capturing the full value of AMI are not purely technical. "There's a cultural challenge as much as a technical one," Wakefield said. "The metering operations groups own the systems, but they're not responsible for delivering advanced distribution or grid-facing capabilities. Without strategic executive leadership visibility and cross-functional ownership, those capabilities simply don't get pursued."

A CHANGED GRID

The survey suggests this is changing. For example, 82 percent of respondents ranked grid visibility and situational awareness as their top future investment priorities. This prioritization reflects how much the grid has changed in the years since smart meters were first deployed. Not only are utilities keen to manage the real-time complexity of a grid that includes far more intermittent renewable generation and bidirectional power flows from distributed energy resources (DERs), but they are also navigating rapid load growth from data centers powering artificial intelligence (AI) applications.

Given the ongoing transformation of the grid, it is not surprising that utilities find the specific capabilities of the latest AMI iterations especially attractive. For example, distributed or edge intelligence is the ability to run applications directly on the meter. These applications could include things like fault detection, real-time load

> *82% of respondents ranked grid visibility and situational awareness as top future investments*

management, and EV charging analysis. With the right smart meter hardware and software, the underlying infrastructure unlocks multiple benefits. "Utilities see it the way you might think about apps on your phone. You may not know exactly what your most important app will be two years from now, but you want a platform to be able to add them as you need them," Wakefield said.

ASSEMBLING EVIDENCE, SHARING KNOWLEDGE

Utilities understand the potential value AMI 2.0 can deliver, a value that appears uniquely suited to the challenges and opportunities facing the grid today. But it's also clear that utilities don't want to repeat the past, when large investments in smart meters failed to unlock their most advanced capabilities.

This helps explain why 90 percent of survey respondents said they want validated use cases, real-world performance data, and credible evidence they can bring to regulators and utility leaders to justify new investments.

The NextWave AMI initiative aims to provide the rigorous, collaborative research needed for utilities to understand what AMI can deliver, what challenges need to be overcome to secure that value, and the confidence to make investments and engage with regulators. "Technology providers can point to compelling use cases, but utilities and regulators understandably want independent validation," Wakefield said. "If EPRI can provide that unbiased, evidence-based perspective, it adds a level of credibility that really matters, especially when those investments are under regulatory scrutiny."

In other words, the NextWave AMI initiative embodies EPRI's traditional role, focusing on independent research, shared knowledge, and serving as an industry convener. In this case, NextWave AMI will pursue its work across three interconnected areas. The top priority is to assemble a comprehensive library of use cases and case studies that cover both legacy AMI deployments and emerging capabilities.

> *90% of respondents want use cases, performance data, and credible evidence to justify new investments*

The use cases are instructive because they describe potential AMI capabilities and the technical requirements to achieve them, while utility deployments illustrate best practices and real-world mistakes. Both are important when considering significant new investments. "It's not just about technical requirements or cost-benefit analysis," Wakefield said. "Utilities really want to know: what actually happened in the field? What worked, what didn't, and what would you do differently?"

The library will mirror AMI's broad capabilities. For example, operational use cases will include fault detection and location, transformer loading analysis, and momentary outage tracking. Customer-focused use cases include EV charging analysis, appliance-level energy disaggregation, and rate plan optimization. The library will also feature emerging AMI 2.0 capabilities, such as DER visibility, integration with advanced distribution management systems (ADMS), and sub-second telemetry to support grid operations.

An initial version of the library is expected to be available to project participants this spring. The ultimate goal is to have a library with hundreds of use cases and case studies that is AI-searchable. This would provide utility engineers with a valuable tool for answering a wide range of specific AMI planning and operational questions.

FRAMEWORKS FOR SUCCESS

Another NextWave AMI area of focus will address some of the foundational issues that have prevented utilities from getting the most out of past AMI deployments. To do that, the initiative will develop reference architectures, blueprints for transitioning from legacy systems, and cybersecurity and communications requirements. More immediately helpful will be a meter failure database that will help utilities understand failure trends and rates in their current AMI deployments, providing visibility that will guide decisions about smart meter replacements.

Utilities considering AMI replacements will face regulatory scrutiny, a process that demands a data-driven assessment of the actual value of smart meters. The challenge to quantifying that value is that the same AMI platform can deliver multiple benefits. "If you're looking at a single use case like fault detection, it may be hard to justify on its own," Wakefield said. "But if that same capability also enables EV detection and load disaggregation, that combined value looks very different."

NextWave AMI will develop cost-benefit analysis tools that capture the holistic benefits of AMI investments. The initiative will also build guidelines and evaluation metrics that utilities can use in their AMI field demonstrations. This will help ensure the industry has a consistent methodology for reporting results to regulators and utility executives weighing new investments.

Many utilities face big decisions about what comes next for smart meters, decisions that could make the grid more manageable, visible, and efficient. But the investments needed to fully leverage AMI are hardly insignificant, especially at a time when affordability is a top concern. NextWave AMI doesn't seek to make those decisions for utilities. But it aims to provide both the evidence and the collective industry knowledge needed to make decisions that best support the grid and serve customers.

EPRI TECHNICAL EXPERT

Matt Wakefield

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Fire Safety Considerations for Electric Vehicles and Charging Stations

What Fleet Managers Need to Know

As electric vehicles (EVs) become an increasingly common part of commercial and utility fleets, questions around fire safety arise. While available data indicate that fires involving electric vehicles may occur less frequently than those involving internal combustion engine (ICE) vehicles, EVs present unique hazards—particularly when a fire involves the high-voltage traction battery or occurs while a vehicle is connected to charging equipment.

This white paper examines these risks with a specific focus on fleet environments, where many vehicles may be parked, charged, or stored together. It outlines practical considerations and emerging best practices that can help fleet managers reduce risk, improve preparedness, and support safe fleet electrification.

EV FIRES: RARE, BUT DIFFERENT

All vehicles, regardless of propulsion technology, can catch fire. Many ignition sources—such as flammable materials, hot mechanical components, and electrical faults—are common across all vehicle types. EVs, however, introduce a unique element when their traction batteries become involved.

Lithium-ion traction batteries store significant amounts of energy that, under certain failure conditions, can trigger thermal runaway. Thermal runaway is a self-sustaining chemical reaction within battery cells that generates heat and flammable gases. Once initiated, it can persist for extended periods, making fires more difficult to control and increasing the risk of re-ignition hours or even days later.

For fleet operators, this distinction matters. EV battery fires can burn for longer durations, require substantially more water to suppress, and pose additional hazards to first responders. These characteristics can increase the likelihood of fire propagation to nearby vehicles and structures, especially in dense fleet parking or charging areas.

WHY FLEET ENVIRONMENTS FACE ELEVATED RISK

Fleet settings present unique challenges compared with single-vehicle incidents. Vehicles are often parked close together, stored in multilevel garages, or charged simultaneously for long periods. In these environments, a single vehicle fire—whether EV or ICE—can quickly escalate.

Research notes that while EV fires are expected to be uncommon, the consequences of a traction battery fire can be significant. Longer firefighting times, extended site closures, and the need to isolate damaged vehicles after an incident all have implications for fleet safety and business continuity. As a result, planning for low-probability, high-impact events is a prudent step for fleet managers transitioning to electric vehicles.

THE TRACTION BATTERY: A CENTRAL SAFETY CONSIDERATION

Modern EVs rely on lithium-ion battery systems that are typically integrated into the vehicle floor and enclosed in sealed, protective housings. Battery sizes range from a few kilowatt-hours in hybrid vehicles to hundreds of kilowatt-hours in heavy-duty electric vehicles.

While these enclosures are designed to protect batteries during normal operation and collisions, they also limit firefighters' ability to directly cool the internal battery components during a fire. In a thermal runaway event, energy stored within the battery itself can sustain the reaction without external fuel sources.

To prevent internal pressure buildup, battery enclosures are vented to allow gases to escape. These gases may be flammable and toxic, reinforcing the importance of evacuation, distance, and professional response. Research emphasizes that a vehicle fire becomes especially challenging when the traction battery is involved, and that response strategies must account for this.

CHARGING ADDS AN ADDITIONAL CONSIDERATION FOR FIRST RESPONDERS

Unlike ICE vehicles, EVs are often "fueled" while parked and unattended. Charging sessions can last for hours, during which vehicles remain connected to the electric grid. This grid connection introduces additional considerations for fire safety planning.

In the event of a fire involving a plugged-in vehicle, firefighters must address not only the fire itself but also the potential for electrical shock from energized equipment. Responders will typically seek to de-energize charging equipment or disconnect the vehicle as part of their initial actions.

For fleet managers, this underscores the importance of clearly marked emergency shutoffs, accessible power disconnects, and coordination with local fire departments. Emergency response planning should explicitly address how charging equipment will be shut down safely during an incident.

BUILDING A FOUNDATION WITH SAFE CHARGING EQUIPMENT

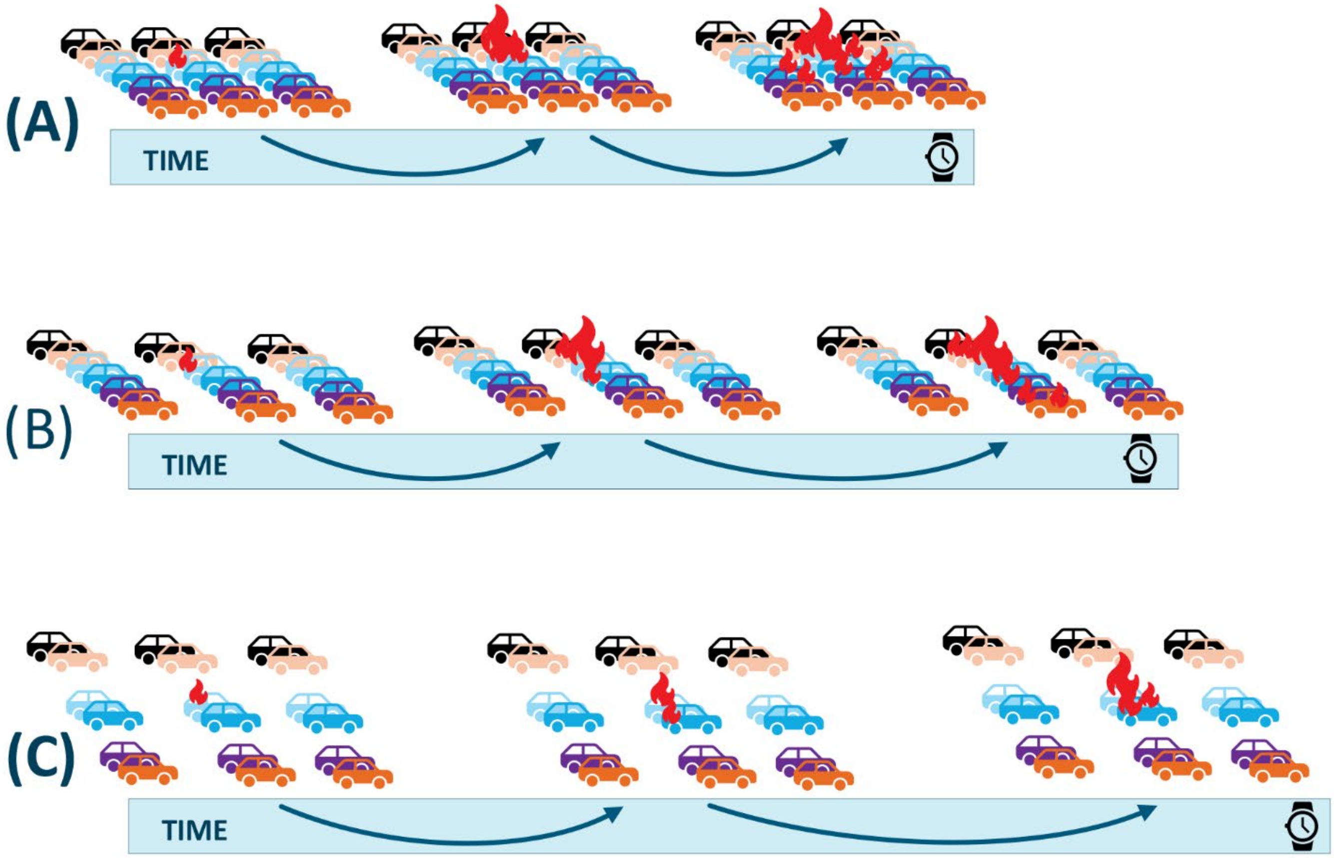
One of the most effective ways to reduce fire risk is to start with safe, properly installed charging infrastructure. EPRI recommends using charging hardware that complies with applicable safety standards and is certified by a nationally recognized testing laboratory.

Charging equipment should be installed in accordance with the National Electrical Code by licensed electricians with EV-specific training and experience. New installations should be inspected during commissioning, including checks for abnormal heating under full-power operation. Hard-wired charging equipment is preferred where feasible, and extension cords should never be used.

Routine inspections are equally important. Periodic visual checks—and, where appropriate, infrared inspections during active charging—can help identify developing issues before they lead to failures.

VEHICLE CHARGING SAFETY STARTS WITH TRAINING

Because vehicles spend long periods connected to chargers, driver and staff awareness plays a critical role in early detection of problems. Fleet personnel should be trained to inspect plugs, inlets, and cables before each charging session and to remove damaged equipment from service immediately.



Fire propagation risk: (A) high risk with tightly packed vehicles; (B) vehicles divided into groups lessens risk and lengthens time to spread; (C) smaller groups lessen risk even further.

Research identifies several warning signs that may indicate a developing fire hazard, including smoke, burning plastic odors, and unusual sounds such as hissing, popping, or crackling. When these signs are present, charging should be stopped if it can be done safely, nearby vehicles or materials should be moved if possible, and first responders should be notified promptly.

Using charging adapters also requires careful attention. Only manufacturer-approved or certified adapters should be used, and adapters should be inspected before each use. Damaged adapters should never be placed into service.

SAFE OPERATION AND STORAGE OF ELECTRIC VEHICLES

Fire safety considerations extend beyond charging into everyday vehicle operation and storage. Vehicles with known or suspected traction battery damage should not be operated until inspected and cleared by a qualified EV technician. Warning indicators related to battery systems should be addressed promptly, and vehicles reporting battery faults should be removed from service.

Storage practices are especially important in fleet environments. EPRI recommends consulting vehicle manufacturers for guidance on both short- and long-term storage procedures, which may vary by make and model. Damaged EVs—particularly those involved in collisions or floods—should be treated as fire risks and stored at least 50 feet away from other vehicles or structures, or in contained areas when available.

Keeping flammable materials away from parked vehicles, providing fire extinguishers near storage areas, and monitoring storage sites through inspections or remote systems can further reduce risk.

PARKING LAYOUTS AND GARAGE DESIGN MATTER

Vehicle spacing is a key factor in fire propagation risk. While no formal industry standard exists for vehicle spacing in fleet fire safety, EPRI emphasizes that increasing the distance between vehicles can reduce the likelihood of fire spread and give first responders more time to arrive.

Multilevel parking garages present additional challenges. Enclosed or partially enclosed spaces can trap heat and smoke, complicating firefighting efforts and evacuation. Fleet operators are encouraged to place EV parking and charging in locations with good access for responders and proximity to water supplies, and to verify compliance with applicable electrical and fire safety codes.

Insurance providers may also impose additional requirements related to charging installations and parking layouts, making early engagement advisable.

PREVENTION, RESPONSE, AND BUSINESS CONTINUITY

Pre-incident planning with local fire departments is one of the most important steps fleet managers can take. Fire departments can assist with site assessments, access routes, utility shutoffs, evacuation procedures, and alignment of emergency response plans with local capabilities.

EPRI's research describes both offensive and defensive firefighting approaches for EV fires. Offensive approaches focus on applying large volumes of water to cool batteries and suppress flames. In contrast, defensive approaches may prioritize containment and monitoring to reduce environmental impact and re-ignition risk. The chosen strategy depends on site conditions, your local fire department's equipment and training, proximity to structures, and life safety considerations.

Because EV fires can disrupt operations for extended periods, fleet managers are also encouraged to plan for business continuity. Alternate access routes, secondary parking locations, and contingency plans can help limit downtime following an incident.

PREPARING FOR A SAFE TRANSITION

As fleets transition to electric vehicles, fire safety planning must evolve alongside vehicle technology. While EVs introduce new hazards, many core fleet principles remain the same: preparedness, training, coordination with first responders, and thoughtful facility design.

By understanding how EV fires differ, recognizing the role of charging infrastructure, and implementing best practices across operations and storage, fleet managers can reduce risk and support a safe, resilient move toward electrified transportation.

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.

EPRI JOURNAL

Image created by Copilot

The Electric Airport

A new EPRI offering draws on decades of experience and wide-ranging expertise to help airports prepare for an electric liftoff.

By Chris Warren

Los Angeles International Airport (LAX) is a city within a city. The airport covers 5.5 square miles and regularly serves well over 70 million passengers annually, making it one of the busiest airports in the nation.

Large airports like LAX need huge amounts of energy to run lighting, heating and cooling, baggage carousels, and fleets of vehicles to move people and equipment. Traditionally, much of the energy needed to power airports—especially ground support equipment (GSE), such as baggage tugs that bring luggage to and from airplanes—has come from fuels like gas and diesel.

But there is increasing interest and investment in electrifying airports. LAX, for example, is in the process of fully electrifying its GSE by 2033, including the pushback tractors that move planes away from the gate to taxi under their own power. Overall, LAX is electrifying about 1,200 vehicles, including the airport's maintenance and operations fleets. Electrification is all part of LAX's broader effort to achieve carbon neutrality in airport operations by 2045.

LAX is by no means alone in its push towards greater electrification. For example, electrification is at the core of the redevelopment of New York's JFK. The airport's new international terminal will be the first in North America to use a fully electric GSE fleet, and all commercially available GSE used at JFK, LaGuardia, and Newark airports must be electric by 2030. A survey released by the American Association of Airport Executives at the end of 2023 found that 100 percent of North American airport operators expected their power needs to grow, driven by decarbonization and electrification mandates and objectives.

WHEN AMBITION MEETS REALITY

Airport electrification ambitions raise important questions for operators. For example, adding new vehicles, including GSEs, electrifying heating and cooling, and other airport operations represent a

"As airports add more electrical load like chargers and electrified equipment, the power infrastructure underneath them becomes more important, not less.

significant increase in load. For airports both large and small, electrical infrastructure was simply not built for this level of demand.

Though important, it's not just about rising electricity demand. According to a report by the National Academies of Sciences, Engineering, and Medicine, peak loads at airports could also double over the next two decades.

Adding large new loads and pushing peak demand higher can introduce power quality issues, such as voltage sags, harmonics, and disturbances that ripple through sensitive airport systems. "As airports add more electrical load like chargers and electrified equipment, the power infrastructure underneath them becomes more important, not less," said Mark Stephens, program manager of EPRI's Industrial Power Quality Assessment group. "The more connected the system, the more places there are for power quality issues to originate and impact operations."

For example, Stephens described how baggage handling systems, moving sidewalks, escalators, and elevators are vulnerable to voltage sags and interruptions. Sudden lapses in power on a moving sidewalk, for example, can pose a safety risk if they result in a fall. Longer interruptions due to power quality issues can frustrate passengers and bring operations to a standstill. "Underneath a large airport, you have what amounts to an industrial plant, with miles of conveyor systems, TSA scanning equipment, and dozens of control panels all part of one continuous baggage operation," Stephens said. "A voltage sag that lasts a fraction of a second can take that entire system offline for hours."

Some of the challenges airports face in pursuing electrification revolve around efficient management and coordination of stakeholder roles. For example, airlines typically own the GSE, airports own charging equipment, and utilities are responsible for grid infrastructure. Myriad questions about roles and responsibilities must be answered. "One of the practical questions that comes up is who pays for the electricity? The airline owns the ground support equipment, the airport owns the charging infrastructure, and the utility bill goes to the airport," said Baskar Vairamohan, an EPRI technical executive. "Working out how to track and allocate those costs is not a technical problem, but it can slow everything down just as much as a technical one."

Optimizing the economics of electrification investments requires smart and coordinated planning. For instance, the timing of charging a new electric GSE will significantly affect the investment's payback time. Charging electric baggage tugs, pushback tractors, and other equipment that replace diesel-powered vehicles during peak demand will significantly increase operational costs and payback times. Off-peak charging lowers those costs but is complicated because GSE must operate during normal airport hours, which often coincide with peak demand.

"Some airports have already made significant investments in electric equipment and now find themselves asking the next set of questions: how do we manage the load we've created, how do we make sure the power quality is there to support it, and how do we keep optimizing as we add more?" said Scott Bishop, a senior technical executive who leads EPRI's Industrial Center of Excellence. "Electrification opens the door to a whole new level of complexity and opportunity."

From Assessment to Action

EPRI has been working with airports for decades to assess their potential for electrification, quantify return on investment (ROI), and identify the grid infrastructure and other equipment requirements needed to make it a reality. EPRI has conducted assessments for both large international airports, such as LAX and Detroit Metropolitan Wayne County Airport, as well as more regional hubs in Birmingham, Alabama, and Orange County, California, focusing on everything from GSE to gate electrification to energy efficiency and power quality.

Airport Energy and Power Quality Walk-Through Assessment Pillars

That collective experience is now being combined with other areas of EPRI expertise to develop a new supplemental project, the Airport Energy and Power Quality Walk-through Assessment, that holistically addresses the challenges and opportunities represented by airport electrification. "This offering brings together the tools and insights we've developed from decades of airport assessments with expertise from across EPRI," Vairamohan said. "The goal is to give airports and utilities a complete picture, not just of the electrification opportunities in front of them, but of everything they need to make those investments work." To achieve that goal, the offering has four pillars: power quality and energy efficiency, demand flexibility, electric transportation, and low-carbon fuels.

Airports can pursue all four pillars or focus on the areas most relevant to where they are in their electrification journey. For example, an airport still in the early stages of planning might begin with a comprehensive assessment of electrification and energy efficiency. One that has already electrified significant portions of its fleet might prioritize demand flexibility to schedule and manage charging, keeping costs down and avoiding grid strain. Another might focus on power quality, assessing whether its existing infrastructure can handle the loads it is about to add without risking critical systems.

A PROVEN PROCESS

To better understand what to expect with the Airport Energy and Power Quality Walk-through Assessment, it's instructive to consider how past EPRI airport electrification assessments have worked and the value they have delivered. An assessment begins with a detailed conversation with airport officials to understand their priorities, existing infrastructure, and near-term goals. Ideally, this initial collaboration includes the local utility to determine whether they offer any funding or incentives to support electrification.

After that initial fact-finding, an EPRI team visits the airport to conduct an equipment inventory, inspect the electrical infrastructure, and interview airline and airport staff. This results in an analysis that identifies electrification opportunities, including which investments offer the best near-term returns.

"The assessment is always driven by what the customer wants," Bishop said. "We go in with a framework, but the priorities come from the airport. Some are focused on reducing emissions to meet a regulatory deadline. Some want to understand what infrastructure they need to build. Some are trying to make the case for a federal grant. The work looks different depending on where they are."

Bishop noted that the utility is never just a bystander in this process. In fact, in several past assessments, the utility itself has initiated and funded the engagement because it recognizes that a rapidly electrifying airport is both a major customer and a significant new load on the local grid. Understanding what loads are coming and when is as important to the utility as it is to the airport. "The utility has a real stake in this," Bishop said. "They want to know what load is coming, how fast, and where on the system it is going to land. An airport assessment gives them that picture, and it allows them to get ahead of the infrastructure requirements rather than react to them."

The benefits of electrification can be substantial. At Albuquerque International Sunport, for example, EPRI's assessment identified 112 pieces of ground support equipment with a clear path to electrification, including baggage tractors, belt loaders, pushback tractors, ground power units, and preconditioned air systems. The analysis projected lifetime savings of nearly $6.75 million in the best-case scenario.

The assessment also revealed how sensitive electrification economics are to planning decisions that might seem operational but are fundamentally financial. For a baggage tug replacing a diesel unit, for instance, off-peak charging produced a payback period of under four years. The same tug charged during peak demand hours produced a negative lifetime return. "Getting the economics right requires understanding the utility rate structure, the airport's operating hours, and how to align charging schedules with the times when electricity is cheapest," Bishop said. "That's not something most airports have the expertise to work through on their own, and it's exactly the kind of analysis that can make the difference between an investment that pays off and one that doesn't."

Charging infrastructure presents its own layer of complexity. Unlike consumer electric vehicles, which benefit from standardized charging protocols, ground support equipment has no universal standard. Different GSE manufacturers use different battery chemistries and communication protocols. The result: a charger that works with one manufacturer's baggage tractor may not work with another's.

"The challenge airports run into is that there's no universal charging standard for ground support equipment the way there is for electric cars," said Arun Patel, CEO of Minit Charger, a leading supplier of GSE charging equipment to airports. "Different manufacturers use different protocols, and if your charger and your vehicle aren't speaking the same language, the equipment simply won't charge. It's a logistical problem that catches a lot of operators off guard."

The breadth of the Airport Energy and Power Quality Walk-through Assessment reflects the scale of the challenge and opportunity of electrification. Power quality assessments draw on EPRI's Industrial Power Quality and Energy Efficiency group, which has conducted more than 430 assessments across industries ranging from semiconductors to food and beverage manufacturing. Demand flexibility work connects airports to EPRI's legacy of research on managed charging and load optimization. Low-carbon fuels expertise leverages EPRI's work on sustainable aviation fuel for airports.

The goal of the Airport Energy and Power Quality Walk-through Assessment, said Vairamohan, is to give airports and their utility partners a phased roadmap that connects near-term investments to long-term goals. "The airports that get this right will be the ones that planned for all of it," Vairamohan said.

EPRI TECHNICAL EXPERTS

Baskar Vairamohan, Mark Stephens, Scott Bishop

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