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EPRI ELECTRIC POWER RESEARCH INSTITUTE

EFFICIENT ELECTRIFICATION

Happy New Year. As 2021 begins, there are many signs pointing to the rapid advancement of efficient electrification in the near term. Despite ongoing challenges presented by the COVID-19 pandemic, EPRI technical research and innovative utility initiatives continue to move forward with remarkable speed, spanning from electric vehicle (EV) charging to electrified heating and cooling to building decarbonization.

In this month's issue, we're taking an in-depth look at three areas of electrification that are growing in importance for power companies: geothermal heat pumps, cybersecurity for EV charging systems, and indoor agriculture. Highlights of these stories are below, along with links to the full stories.

Geothermal Energy: A New Utility Business Model?

Despite being the most energy-efficient HVAC technology, geothermal heat pumps have remained a niche market for decades because of high capital and installation costs, holding just 1% of the HVAC market. But the beginnings of a potentially tectonic shift in how buildings are heated and cooled may be afoot. In states with ambitious new climate laws, natural gas utilities are investigating the possibility of pivoting to a new business model that involves deploying and managing community-scale geothermal systems that circulate water in large underground pipe networks and exchange energy among numerous buildings.

Because such systems have structural similarities with natural gas pipe networks—for example, both connect buildings with high-density polyethylene pipes—gas utilities are potentially a good fit to install, operate, and maintain them. This pivot presents a significant opportunity to electrify buildings on a large scale and reduce greenhouse gas emissions.

State regulators in Massachusetts recently approved a community-scale geothermal pilot proposed by Eversource Energy. "We see synergies between geothermal systems and our existing gas and electric systems, and there could be economies of scale and better electric grid efficiencies if we can utilize the geothermal systems to shave and better manage peak demand," said Nikki Bruno, director of clean technologies at Eversource.

Cybersecurity for High-Power, Fast Charging

The development of high-power, fast charging technologies for EVs—which include systems that can support power levels of 250 kilowatts or more—could turbo-charge the growth of the EV market by enabling much faster charging for more vehicles and by addressing range anxiety. Yet, cybersecurity experts are concerned about several potential risks that these and other fast charging technologies pose. For example, an unaddressed security vulnerability could result in a large number of EVs charging simultaneously, leading to an unexpectedly high peak demand.

"It's essential to get ahead of cybersecurity risks for EV charging because electric transportation is a relatively new market," said Rish Ghatikar, an EPRI expert on information and communication technologies for distributed energy resources. "A major security failure could damage the industry's credibility and slow EV adoption."

Recognizing the absence of uniform methods and actionable tools to assess the cybersecurity impacts of the various parts of EV charging systems, EPRI has been working to fill this critical gap since 2016. An EPRI-led collaborative team brings together EV manufacturers, charging station manufacturers, charging network operators, utilities, national laboratories, government agencies, and standards organizations to define, develop, and validate cybersecurity technologies for high-power, fast charging.

EPRI, Utilities Look at Energy and Grid Impacts of Indoor Agriculture

Allied Market Research projects that the global market for vertical indoor farming will grow nearly 25% each year between 2019 and 2026, when it will be worth $12.77 billion. Indoor agriculture startup Plenty has attracted investment capital from the likes of Amazon CEO Jeff Bezos and former Google chairman Eric Schmidt. At the same time, there have been high-profile bankruptcies: high power and labor costs led to the closure of PodPonics and FarmedHere, which operated the world's largest vertical farms.

Despite these mixed signals, the indoor agriculture industry appears to be on its way to securing a sizable share of the agricultural market. Because these facilities can consume significant electricity for lighting, heating, and cooling, utilities can get ahead of the trend by preparing for significant new loads in their service territories.

EPRI is deploying numerous 320-square-foot container farms around the country in collaboration with utilities. These projects are expected to give the utilities a better understanding of the industry's potential future electricity use—insights that could inform their grid planning and operations.

New York, Massachusetts Utilities Investigate Potential New Business Model: Community-Scale Geothermal

It was a big moment in the career of John Ciovacco, president of Aztech Geothermal, a designer and installer of geothermal heat pump systems in upstate New York. At the National Society of Professional Engineers' annual conference in February 2020, Ciovacco delivered a presentation called, "Are Electric Heat Pumps Ready to Replace Natural Gas?" to an audience that included both electric utility and natural gas utility engineers. A casual observer might have considered Ciovacco's bold question to be overly optimistic. After all, geothermal heat pump systems—which use underground water pipes called "ground loops" to absorb the earth's heat and deliver it to buildings—have remained a niche market for decades, mainly because of higher capital costs relative to other heating and cooling technologies.

But Ciovacco's presentation was based on hard facts, not wishful thinking. He explained that New York's ambitious new climate law, which requires the state to cut greenhouse gas emissions to 85% below 1990 levels by 2050, effectively mandates that buildings stop burning fossil fuels for heating and cooling by 2050. Today, heating and cooling in buildings account for 32% of the state's combustion-related greenhouse gas emissions. "In the next 30 years, the vast majority of New York state's buildings will need to convert to electrically driven space heating and hot water," Ciovacco said.

The big question is, how will this conversion happen? Some natural gas utilities in New York are investigating the possibility of pivoting to a new business model: managing community-scale geothermal systems that circulate water in large underground pipe networks and exchange energy among numerous buildings. Because such systems have structural similarities with natural gas pipe networks—for example, both connect buildings with high-density polyethylene pipes—gas utilities are potentially a good fit to install, operate, and maintain them. National Grid and Con Edison are developing pilot projects in New York, some of which have been proposed to New York regulators. These projects offer an opportunity for the utilities to apply their decades of experience with natural gas infrastructure to geothermal energy.

Similar geothermal proposals from gas utilities are on the table in Massachusetts, which recently enacted a climate law mandating an 80% reduction in greenhouse gas emissions by 2050. In October, state regulators approved a $10.2 million demonstration project proposed by Eversource Energy. The developments in New York and Massachusetts could be the bellwether of broader implementation of utility-scale geothermal if more states adopt climate mandates.

Geothermal: Super-Efficient but Expensive

Geothermal heat pump systems have been used to heat and cool U.S. homes and businesses since the 1940s. In the winter, water circulating in underground pipes absorbs heat from the ground. The pipes deliver the water into the building, where a heat pump concentrates and transfers the heat to the building. In the summer, the heat pump extracts heat out of buildings and moves it into the ground via the same water pipes. This process takes advantage of the earth's constant, moderate temperature: While air temperatures vary by season, temperatures of the ground 10 to 20 feet below the surface typically remain between 50°F and 60°F year-round—warmer than the winter air and cooler than the summer air. As a result, geothermal heat pumps are the most efficient heating and cooling systems, with a coefficient of performance in the 3 to 5 range. In other words, one unit of electricity used to operate a heat pump can extract 3 to 5 times

In July 2019, New York Governor Andrew Cuomo signed the Climate Leadership and Community Protection Act. The climate law's ambitious greenhouse gas reduction goal effectively mandates that buildings in New York stop burning fossil fuels for heating and cooling by 2050. Photo courtesy of the press office of Governor Cuomo.

the energy from the ground. (This is sometimes expressed as 300% to 500% efficient, based on the potential energy of the electricity needed to run the geothermal heat pump system and the total output energy to the building.) Efficiencies of other heating technologies are considerably less: 200-250% for air-source heat pumps in cold climates, 95% for condensing natural gas and propane furnaces, and 85% for oil and kerosene-based heating systems. (These efficiencies are estimates and can vary widely based on numerous installation- and product-related factors.)

However, geothermal systems can have several times the installation cost of air-source heat pump systems because they require drilling in the ground, piping for the ground loop, and other expensive underground work. While an air-source heat pump and geothermal heat pump share common mechanical components, the geothermal customer buys a more specialized version of the equipment and needs to pay for the installation of a ground loop. Even though oil and propane customers installing a geothermal system can recoup the additional costs through energy savings over 5-10 years, high upfront costs have limited the geothermal market. According to U.S. Energy Information Administration, geothermal systems represent just 1% of the total HVAC market.

Community-scale geothermal is not a novel concept, though its execution in the United States is relatively rare. The systems that have been deployed have consistently demonstrated impressive results. For example, a system installed at Colorado Mesa University uses only one-third of the water and a quarter of the energy that would be needed by a conventional system of natural gas boilers and cooling towers while supplying 100% of the heating and 79% of the cooling energy for all connected buildings. It has saved the university $1 million per year in energy costs and reduced fossil fuel emissions from heating and cooling by 75%. In addition, as more buildings with more diverse energy uses were strategically connected to the network, overall system efficiency improved.

Massachusetts-based climate non-profit HEET (Home Energy Efficiency Team) is advancing a “GeoMicroDistrict” concept, which refers to a shared ground loop serving a street segment, with thermal energy being transferred between individual buildings and the ground loop. A 2019 study by HEET and BuroHappold Engineering examined the feasibility of replacing aging natural gas infrastructure in Massachusetts with GeoMicroDistricts and linking them over time to build a large thermal distribution system. The study, which involved analyzing building and site conditions throughout the state, found that as the system grows larger and the diversity of energy uses increases, the overall efficiency improves, with more potential for energy storage and load sharing. For example, a supermarket with numerous refrigerators can help balance heating of houses. A second key finding: based on today’s electric generation mix in Massachusetts, GeoMicroDistricts connected to geothermal heat pumps in buildings can potentially reduce greenhouse gas emissions from heating, cooling, and hot water by nearly 60%. These emissions would decrease further with increasing renewable energy penetration on the electric grid.

The study advocates for a utility-scale approach in which existing natural gas companies install, operate, and maintain the GeoMicroDistricts. HEET is in discussions with several utilities about piloting the GeoMicroDistrict concept, including Eversource Energy and National Grid.

National Grid: After Promising Early Results, Bigger Proposals

In 2016, National Grid’s natural gas business deployed a community geothermal demonstration project that connected 10 houses in Riverhead, New York on Long Island. The houses, located in an area without access to natural gas, were previously heated by oil or kerosene and cooled by electric air conditioning units. The new systems performed well even in extended cold and warm periods,

Various components of the shared ground-loop system during construction of National Grid’s Riverhead demonstration project on Long Island. Photo courtesy of National Grid.

with coefficients of performance between 2.2 and 3.5. The customers saved 33-67% on heating costs while reporting improved air quality, quiet equipment operation, and more even distribution of hot and cold air. No backup heating was needed, so the customers were able to completely retire their original systems.

Encouraged by the project's success, National Grid in April 2019 submitted a proposal to the New York Public Service Commission to expand this demonstration project in New York's downstate region, with a focus on low- and moderate-income residential customers and commercial and industrial customers that are outside the gas network. National Grid would install and own the ground loops while partnering with geothermal installers to deploy the in-home equipment. A flat monthly fee paid by participating customers would offset the cost of the engineering and design work as well as a portion of the loops. The company said it also would examine how best to operate the systems in areas with high penetration of natural gas infrastructure.

"Our primary intention with this proposed project is to work with customers outside the natural gas network as they are generally paying the highest cost for their energy and—in the case of delivered fuel customers—have the potential to reduce their carbon emissions by the greatest amount," said Owen Brady-Traczyk, manager of National Grid's Future of Heat program. "But we also want to begin investigating how we would manage a geothermal system located inside our gas network. We would like to explore issues like supporting gas customers who choose to transition to geothermal and safely deploying geothermal infrastructure in the same rights-of-way where gas infrastructure is located."

In July 2020, National Grid proposed to deploy 2,600 tons of shared geothermal ground loops serving the equivalent of 650 single-family homes in its upstate New York natural gas service territory. As part of the four-year, $12.9-million project, the utility would own and operate the ground loops and contract with geothermal suppliers who would install the loops and above-ground equipment (such as heat pumps and ductwork in buildings). Customers would include those that use delivered fuels like propane and oil, customers who are far away from gas mains (large distribution pipes), and new residential construction customers. The utility said that it also would evaluate the potential for geothermal conversion for existing gas heat customers who are served by a segment of leak-prone gas pipe. The idea would be to remove that segment from service and replace it with geothermal infrastructure in the same right-of-way.

A flat monthly fee paid by participating customers would enable the utility to fully recover its ground loop investments. Through this approach, National Grid would depreciate its investments over 50 years, a conservative estimated life of the shared loop equipment (which could last 100 years or more). Depreciation is the practice of spreading the expense of a fixed asset over the course of its useful life.

"Fifty years is also the depreciation period that we use for some of our natural gas piping," said Brady-Traczyk. "We wanted to make the financial evaluation of geothermal infrastructure equivalent to that of our gas infrastructure so that we can evaluate them side by side. As we learn more about geothermal technology and—hopefully—receive approval from state regulators to deploy it, we will review the useful life and depreciation period to ensure that we are doing everything we can to facilitate adoption."

"As an entity with access to low-cost capital and the ability to recover costs over long periods of time, [National Grid] is well-positioned to invest in long-lived thermal infrastructure," the proposal said. "By amortizing the costs of geothermal loops over their useful lives and charging participating customers for access to the loop over time, [National Grid] can make access to this technology more affordable for customers…. A gas utility also is well-positioned to support construction and oversee long-term operation of the geothermal ground loop infrastructure because gas engineers and construction personnel are already experienced in the design and installation of underground plastic pipe systems."

The pilots will examine the cost reductions enabled by scaling up geothermal and shed light on the circumstances where shared ground loop systems are cost-effective. "To reduce capital costs of community-scale geothermal, how can we apply our experience coordinating with construction companies, municipalities, customers, and other stakeholders in deploying and operating these projects?" said Brady-Traczyk. "How much can we lower costs by enabling energy exchange among large numbers of customers with diverse load profiles? These are some of the questions we want to explore."

Insights from these projects can inform the utility's decisions about its future investments in geothermal technology. "National Grid has gas-only, electric-only, and mixed service territories," said Brady-Traczyk. "This allows us to understand how the clean energy transition impacts both sides of the energy system. How can we deploy geothermal technology to maximize benefits for the gas and electric systems and appropriately allocate costs? How do we satisfy our statutory obligation to provide natural gas to customers who still want it?"

Con Edison: Pilots in the Works, Heat as a Service

In early 2019, Con Edison—which provides electric, gas, and steam service for the 10 million people who live in New York City and Westchester County—announced a moratorium on new natural gas hookups in Westchester because the utility's gas pipeline capacity could not accommodate increasing demand. To help mitigate demand, Con Edison partnered with Dandelion Energy, a geothermal installer and Google X offshoot, to provide Westchester residents with an alternative to gas- and oil-based heating. More than 100 residents have opted for the geothermal installation to date, receiving significant rebates from both Con Edison and New York state. Con Edison has since expanded its rebate offerings to all qualified geothermal installers as part of the state's Clean Heat program.

Con Edison's natural gas business is planning community-based pilots in downstate New York that would involve removing old natural gas infrastructure and replacing it with geothermal ground loops in the same rights-of-way. "It's a concept under development," said William Xia, Con Edison's program manager for electrification and gas alternatives. "We want to better understand the technical and economic feasibility of a community-scale geothermal system." In a December 2020 submission to the New York Public Service Commission, Con Edison said that it had conducted engineering analyses and other technical studies to identify 19 potential sites for a community-scale geothermal system. A Con Edison press release from early 2020 noted that if these efforts had promising results, the utility "will test the concept of heating an entire neighborhood with clean geothermal energy."

In July 2020, Orange and Rockland, a Con Edison subsidiary that serves the northwestern suburbs of New York City, announced that it was seeking a development partner to build a utility-owned, community-scale heat pump project for residential heating and cooling, with a focus on low- to -moderate-income customers. The three-year demonstration project will deploy infrastructure for both geothermal and air-source heat pumps while examining various approaches to customer outreach, utility investment, rate design, and cost recovery models.

Other changes at Con Edison hint at a shift from natural gas to other heating options. As reported in S&P Global Market Intelligence, CEO John McAvoy said in an August 2020 investor presentation that the company would stop investing in long-haul natural gas pipelines. During the same month, Con Edison requested funding from the New York Public Service Commission for a "Heat as a Service" program, in which third-party technology vendors would invest the upfront capital to own and maintain heating and cooling equipment at customer sites. Customers would pay a monthly fee for the service.

Eversource Energy: Green Light for Big Demonstration Project

In an October 2020 order, the Massachusetts Department of Public Utilities approved a proposal from Eversource's natural gas business (NSTAR Gas) to implement a three-year, $10.2 million geothermal demonstration project in a dense mixed-use, residential/commercial neighborhood with diverse thermal energy needs and loads. The mixed-use site can potentially enable Eversource to better understand the efficiency benefits of serving customers with different heating and cooling needs on the same network. The site is expected to have roughly 100 customers with a combination of residential and commercial buildings, pending the final site selection.

In its proposal, Eversource said that the project is intended to test the viability of a non-gas thermal distribution model, assess the technology's scalability, costs, and benefits, and provide real-world experience in building, operating, and maintaining large geothermal networks. The company also seeks insights on rate structures, monitoring, and system metering. Eversource will contract with private companies to install the geothermal network and will own and maintain the network equipment outside the buildings. It will be responsible for monitoring various aspects of the network's performance, such as temperature and pressure in the pipes. The participating residential and commercial customers will own and maintain heat pumps, ductwork, and other equipment inside buildings and pay a flat monthly fee for the heating and cooling service.

Pipes being installed for Colorado Mesa University's campus geothermal system. Photo courtesy of Colorado Mesa University.

"We expect the geothermal pilot to test whether the technology is a feasible alternative for oil, propane, and natural gas customers, what the right business model looks like, what environmental value is delivered, and how well this thermal option meets customer expectations," said Nikki Bruno, director of clean technologies at Eversource.

The Eversource proposal noted that the company's natural gas experience positions it well to deploy geothermal. It pointed to several common aspects of geothermal and natural gas networks, such as capital-intensive projects, deployment and operation of long-lived underground infrastructure in public or private rights-of-way, and condition monitoring in a pipe network.

In its order, the Department of Public Utilities encouraged Eversource to consider incorporating existing natural gas customers in the project and to study the scalability of networked geothermal to serve such customers.

A Glimpse of Geothermal's Future

Given that utilities are still in the early learning phase of community-scale geothermal, it's premature to speculate on the new busi-

ness models that utilities may adopt. There will likely be numerous roles for the various stakeholders, which include regulated utilities, unregulated energy companies, and private geothermal suppliers and installers.

“We’re taking a holistic approach,” said Con Edison’s Xia. “We are open to working with many different stakeholders to see if different business models work.”

How might large utility investments in community-scale geothermal impact heat pump installers? According to Aztech Geothermal’s Ciovacco, few installers today have the skills, expertise, and equipment needed to deploy the ground infrastructure of geothermal systems—work that includes fusing pipes and using excavators to dig in the ground.

“If the utility installs the ground loops, then practically any HVAC installer can install the geothermal heat pumps inside the building because they are very similar to equipment they install today,” said Ciovacco. “It would make every HVAC contractor one manufacturers’ training course away from installing a geothermal system. At the same time, the upfront costs of geothermal would be comparable to the costs of installing conventional heating and cooling equipment.”

With widespread deployment of community-scale geothermal systems, utilities could become thermal distribution managers. “They would predict thermal demand and make real-time decisions to move or store energy,” said Zeyneb Magavi, HEET’s co-executive director. “It’s a similar concept as the electric grid, where operators are balancing renewable energy generation with electricity use. The ideal is balanced heating and cooling energy use over the course of a year. If the system is not perfectly balanced, it’s not the end of the world. The utility can add a boiler, chiller, or new customers to help balance it.”

According to Zeyneb, utility-scale geothermal could lead to valuable synergies with electric grid operations. For example, if wind power plants are producing excess energy at night when demand is low, that power could be stored in the ground as thermal energy for future use by the geothermal network.

“If natural gas utilities are deploying new underground geothermal infrastructure, why not coordinate with electric utilities and underground the power lines along with the water pipes in the same rights-of-way?” said Zeyneb.

Community geothermal systems have the potential to reduce summer electric peaks because geothermal heat pumps use less electricity for cooling relative to air-source heat pumps. Winter peaks could grow significantly as geothermal heat pumps replace heating powered by natural gas, propane and oil, but these peaks could be more consistent across changing weather conditions.

“During a heat wave in the summer or a polar vortex in the winter, the ground is still the same temperature, so there’s a consistent thermal energy source all the time,” said Zeyneb.

“We see synergies between geothermal systems and our existing gas and electric systems, and there could be economies of scale and better electric grid efficiencies if we can utilize the geothermal systems to shave and better manage peak demand,” said Eversource’s Bruno. “In this way, future utility operations would be about being the holistic energy provider for the customer rather than being the gas or electric utility only. We expect our geothermal pilot to shape our thinking on these future operations.”

“There is a lot of innovation happening in geothermal,” said National Grid’s Brady-Traczyk. “But it’s not easy to make these changes quickly because we need to carefully think about what the changes mean. Dialogue is important. We plan to share our data with all stakeholders to inform thoughtful investments.”

EPRI-Led Collaborative Team Advances Cybersecurity for High-Power, Fast EV Charging

For several years, the U.S. Navy has been expanding its electric vehicle (EV) fleets, and today it has approximately one thousand EVs on its U.S. bases. As these fleets continue to grow and as large EVs such as trucks and buses become more widely available, the Navy is investigating the deployment of fast charging technologies, including systems that supply 50 kilowatts of direct current (DC) power.

"This power level can easily support the Navy's light-duty EV fleet," said David Cook, an EV expert at the Naval Facilities Engineering and Expeditionary Warfare Center, which tests and integrates new technologies to improve the readiness and resilience of naval shore facilities.

Cook is also closely watching the development of high-power DC fast charging technologies that can support power levels of 250 kilowatts or more. For context, heating, cooling, lighting, and other end uses in a 25,000 square-foot building may use about 250 kilowatts. Chargers with lower power levels, known as Level 1 and Level 2 chargers, are 6.6 kilowatts and 50-150 kilowatts, respectively.

"In the future, high-power, fast charging systems can potentially enable the Navy to expand its use of electric buses and other heavy-duty EVs as well as EVs for high-mileage applications, such as passenger shuttles," said Cook. "Charging buses with Level 2 alternating current chargers could take days, as compared with 20 or 30 minutes for a high-power, fast charging system. Passenger shuttles do not have the time for extended charging in their daily schedules. High-power, fast charging times more closely resemble conventional fueling, addressing a common concern for prospective EV users."

Cook adds that implementing high-power, fast charging systems must be done with great care.

"While these higher power charging stations are faster and serve more vehicles, they require further security evaluation," said Cook. "We want to remain proactive and vigilant to ensure EVs and other new energy technologies include the latest security features."

Cook and his Alternative Fuel Vehicle Team at the Expeditionary Warfare Center plan to use new EPRI software designed to evaluate potential vulnerabilities and control strategies for high-power charging systems. "Modeling the risks allows naval facilities managers to recommend and incorporate security features early in the procurement process with charging station manufacturers," said Cook. "This ultimately saves money by avoiding field retrofits and mitigating potential threats before they are widespread."

The software, called the Integrated Grid Security Risk Management Tool, is one of several outcomes of an EPRI-led collaborative team that is defining, developing, and validating high-power fast charging cybersecurity technologies. The diverse members of the EV Infrastructure Cybersecurity Working Group include EV manufactur-

This fast charging system deployed by Electrify America at San Francisco Premium Outlets supports a power level of 350 kilowatts. Photo courtesy of Electrify America.

ers, charging station manufacturers, charging network operators, utilities, national laboratories, government agencies, and standards organizations. More than a hundred participants have met monthly since 2018. Lab testing has occurred at EPRI's Cybersecurity Research Laboratory, Argonne National Laboratory, and National Renewable Energy Laboratory.

Potential Grid Reliability Impacts

While high-power, fast charging systems offer great potential to reduce range anxiety and promote vehicle electrification, cybersecurity experts are concerned about several potential risks they pose. For example, adversaries could steal customer payment information during charging transactions, use vehicle global positioning systems (GPS) to locate or track drivers, disable charging infrastructure, or launch viruses into EVs or grid infrastructure. An unaddressed security vulnerability could result in a large number of EVs charging simultaneously, leading to an unexpectedly high peak demand. It could also make numerous EVs discharge simultaneously, resulting in an oversupply of power.

"A breach that causes a rapid, large swing in electricity demand or supply can adversely impact grid reliability," said Rish Ghatikar, an EPRI expert on information and communication technologies for distributed energy resources. "It's essential to get ahead of cybersecurity risks for EV charging because electric transportation is a relatively new market. A major security failure could damage the industry's credibility and slow EV adoption."

"EVs are the fastest growing segments of the automotive industry and are increasingly connected with customers, the grid, and systems that handle financial and other sensitive information," said Sunil Chhaya, an EPRI expert on EV-grid integration. "A breach in any communications link in EV charging systems could have far-reaching consequences. Recognizing the absence of uniform methods and actionable tools to assess the cybersecurity impacts of the various parts of EV charging systems, EPRI has been working to fill this critical gap since 2016. Our investigations aim to develop tools that industry stakeholders can use to harden real-world EV charging deployments."

Security Down to the Component Level

To implement robust cybersecurity for high-power, fast charging systems, security measures are needed for dozens of connected sub-systems (such as EVs, charging stations, and utilities) and components (such as vehicle telematics systems, customer smartphones, charging equipment, utility demand response systems, and servers managed by charging station operators).

As a first step, the EV Infrastructure Cybersecurity Working Group characterized the communications and data exchanges among the sub-systems and components. Next, they assessed the threats and risks that these posed to users and the grid and recommended controls to address the threats. The three labs have simulated cyberattacks on various components to determine if the controls needed improvements.

"We have identified all the components, how they communicate, and what information they potentially expose," said Ghatikar. "It's a complex system, but it's a known complexity."

An example of a control recommended by the working group is encryption of consumers' credit card information. "If credit card information is not encrypted, a hacker can steal it by accessing the systems where it is stored," said Ghatikar. "We also recommended against storing the information locally at the charging station, which would make it easier to steal."

The team created a large diagram known as a reference network architecture that shows the connections among sub-systems and components, the information that flows through them, the stakeholders that operate them, and the vulnerabilities.

Finally, the group developed the Integrated Grid Security Risk Management Tool, which is essentially a digital version of the reference architecture. Utilities, charging station manufacturers, EV manufacturers, facilities managers, charging station operators, and other stakeholders can use the publicly available Web-based tool to evaluate cybersecurity risks and identify necessary controls for EV charging systems under construction. The tool enables users to navigate through each subsystem and zoom in on component-level physical and communication interfaces to view the risks, risk types, and recommended controls. It is expected to be published in Spring 2021 and can be applied to high-power DC fast charging systems, DC fast charging systems, and Level 2 chargers.

"We're interested in this tool because it's been comprehensively tested and peer-reviewed by government and industry organizations with a mutual interest in a secure electric power grid," said the Navy's David Cook.

EPRI also has developed a prototype for a secure network interface card, which transmits the majority of high-power, fast charging communications. "The prototype integrates cybersecurity and physical security to enable a secure link among EVs, EV charging stations, charging station operators, and utilities," said EPRI's Chhaya. "We plan to open-source the hardware and software designs to inform the card's standardization across manufacturers."

For more details on EPRI research on cybersecurity for high-power, fast charging systems, contact EPRI's Rish Ghatikar (gghatikar@epri.com, 650-855-8749) or Sunil Chhaya (schhaya@epri.com, 650-855-2148).

Can Indoor Agriculture Help Feed a Growing World?

Penny McBride has a uniquely kaleidoscopic view of agriculture. As a kid, McBride grew up on the large Colorado farm and ranch that her grandfather started. Later, she worked as a chef at a restaurant in Jackson, Wyoming. After her time in the kitchen, McBride spent years launching Vertical Harvest, a three-story hydroponic indoor farm in Jackson. Hydroponic farming is a plant-growing method that uses materials such as coconut fiber and peat moss instead of soil. Today, Vertical Harvest provides 100,000 pounds of fresh tomatoes, lettuce, and other produce each year to local restaurants and grocery stores.

To McBride, 2020 has highlighted the inadequacies of America's traditional systems for growing and transporting food as well as the important role indoor agriculture will likely play in the future. "With COVID, we're really seeing the problems with our supply chains and that emphasizes the need for locally-grown produce," said McBride, who is now chief operating officer at Delaware-based Second Chances Farm, an indoor farm that provides training, mentoring, and employment to people who were formerly incarcerated.

Even before COVID-related supply chain disruptions resulted in some empty grocery store shelves, there was ample evidence of the environmental and nutritional shortcomings of a food system that depends on transporting food long distances. An often-cited study by Iowa State University found that 30 types of conventional produce traveled an average of nearly 1,500 miles from farm to point of sale. During transportation, produce can lose significant portions of its vitamin content. For instance, research by the University of California at Davis found that vegetables lose 15-77% of their vitamin C within a week of harvest.

Many Potential Benefits of Indoor Agriculture

Indoor agriculture refers to the greenhouses, warehouses, converted or specially built shipping containers, and other indoor facilities that grow produce using a combination of electric lighting, HVAC equipment, building controls, automation, and, in some cases, artificial intelligence.

Indoor agriculture's global growth is being driven by its numerous potential benefits. It eliminates fossil-fuel-powered farm equipment as well as the field runoff of fertilizer and pesticides that pollute rivers, streams, and oceans. It requires minimal to no soil, which is becoming increasingly important. The United Nations estimates that one-third of the world's topsoil is degraded and the remainder could be rendered useless for agriculture within 60 years as a result of chemical-heavy farming, deforestation, and climate change.

Indoor agriculture also reduces the amount of water needed to produce crops. According to the Vertical Farming Institute, an industry trade group, vertical farms require up to 95% less water than traditional outdoor farms.

Crops grown indoors can also be largely insulated from droughts and other severe weather related to climate change. "With indoor agriculture, we are looking to create a perfect environment for a plant," said Carl Sams, a professor of crop physiology at the University of Tennessee Institute of Agriculture. "A big advantage is you take away the risk of droughts and other natural events that may reduce food supply in the field."

An indoor agriculture facility operated by AeroFarms. Photo courtesy of AeroFarms.

In many instances, indoor agriculture is significantly more productive than traditional farming. “Outdoor lettuce averages 26 weeks per crop, so that’s roughly 2 crops a year,” said Frank Sharp, a principal technical leader at EPRI who leads research on indoor agriculture and its implications for the electric power industry. “Some indoor lettuce can be produced in as little as six to eight weeks, which is a game changer.”

Time magazine recognized indoor farming company AeroFarms as one of its 100 Best Inventions of 2019, noting that its cultivation of greens is 390 times more productive per square foot compared to traditional agriculture.

Greater productivity with a much smaller environmental footprint is needed to feed a growing global population. “If we look at the United Nations’ forecasts, we are going to have another 2 billion mouths to feed by 2050 and we have already used about 80% of the arable farmland in the world,” said EPRI’s Sharp. “Indoor agriculture provides a way to use fewer resources to meet the growing demand.”

Despite Big Announcements and Investments, Challenges Remain

Allied Market Research projects that the global market for vertical farming will grow nearly 25% each year between 2019 and 2026, when it will be worth $12.77 billion. In the U.S., vertical farming startup Plenty Unlimited Inc. has attracted investment capital from the likes of Amazon CEO Jeff Bezos and former Google chairman Eric Schmidt. The company claims that its production volumes are 350 times greater per acre than field farming. It recently announced a deal to provide baby arugula, baby kale, and other produce to more than 430 Albertsons grocery stores in California and unveiled a partnership to grow strawberries year-round for the berry company Driscoll’s.

AeroFarms converted a nightclub and former steel mill in downtown Newark, New Jersey to produce greens and is building one of the world’s largest indoor farms in Danville, Virginia as well as a 90,000-square-foot R&D farm in Abu Dhabi in the United Arab Emirates.

Despite these promising signs, the indoor agriculture industry faces persistent hurdles, including the challenge of generating enough revenue to pay for the necessary infrastructure. It can be very power-intensive to maintain a stable, controlled growing environment 24/7. According to the market research firm IDTechEx, vertical farm operators often struggle with difficult tradeoffs between “the high start-up costs of automated, high-tech facilities and the high operating costs of more manual facilities with less advanced climate controls.”

High-profile bankruptcies illustrate these challenges. For example, high power and labor costs led to the closure of PodPonics and FarmedHere. In a summary of its research, IDTechEx reported that very few vertical farming companies are profitable.

“All the technology and automation has a high cost, and the price of a head of lettuce is only going to get you so much,” said McBride.

Not all crops are profitable to grow indoors. Vertical farms tend to grow lettuce, greens, strawberries, and herbs for high-end restaurants and grocery stores. Container farms focus on crops that can be grown efficiently in small spaces—including greens and herbs—and are sold to nearby restaurants or at farmers markets.

Large greenhouses cultivate a wider but still limited range of produce that includes tomatoes and peppers along with the greens and herbs that other indoor growers produce. Greenhouses tend to be more competitive with conventional agriculture because they don’t need as much artificial light, lowering costs. “Indoor crop production is most commonly used for high-value crops and crops that have a short shelf life,” said EPRI’s Sharp. “Can you grow corn and wheat indoors? Absolutely. But we don’t see people doing it.”

A greenhouse in North America that uses a controlled environment to optimize agricultural production

McBride expects indoor farming companies to investigate the financial viability of crops that aren't targeted to upscale restaurants and grocery stores. "Maybe it's medicinal plants besides cannabis," she said. "Maybe it's more high-value produce aside from microgreens. We need to grow more things that more people need."

While there is considerable focus today on building large indoor farming facilities that take advantage of economies of scale, the future of the industry may include a mix of big and small operations—similar to outdoor farming.

"I expect that we are going to find places where smaller farms can serve food deserts and underserved communities," said the University of Tennessee's Sams, who sees the role of academia as providing research and training to improve the supply of affordable, nutritious food to as many people as possible. "Instead of making dollars of profit per unit, maybe you're making cents of profit but selling enough units to make money. To do that, smaller farms that don't have economies of scale will need to be as energy efficient as possible and optimize lighting and plant fertility."

Implications for Utilities

The expected growth of the indoor agriculture industry could result in new industrial-scale loads that are large enough to have impacts on grid operations and planning. Indoor farms can have very large growing areas, requiring a great deal of electricity to power lighting, HVAC systems, monitoring systems, and other end uses. For example, Appharvest recently opened a 2.76 million-square-foot greenhouse.

For a sense of just how much electricity may be needed, consider a 2017 study by the German Aerospace Center and the Association for Vertical Farming, which conceptualized an optimized vertical farming facility with a 54,000-square-foot growing area for leafy greens. The authors found that total annual electricity demand would be about 17,300 megawatt-hours, with lighting alone accounting for about 12,100 megawatt-hours. For context, a small auto assembly plant consumes about 78,000 megawatt-hours per year, according to the U.S. Environmental Protection Agency.

In some cases, an indoor farm's load can be shifted in ways that benefit the grid. For example, greenhouses augment natural sunlight with artificial lighting (particularly when sunlight is not available), offering some flexibility around when artificial lights are turned on and off to support utility load-shifting programs. The degree of flexibility may vary by season. In contrast, vertical farms that rely exclusively on artificial lighting may have much less load-shifting flexibility.

Utilities can engage with companies that are considering locating new indoor farms in their service territories. "They can provide rebates on lighting and other farm equipment and also encourage farms to operate during off-peak hours by offering special electricity rates," said Sharp. "Because labor is the highest cost at an indoor farm—electricity is the second highest—incentives to encourage off-peak operation have to be significant enough to offset the higher labor costs of having people work during non-traditional hours."

A utility also can benefit from indoor farms in its service area because they use much less water than traditional field agriculture. "Utilities are a resource manager for the community and also are large water consumers," said Sharp. "Indoor agriculture provides another way for utilities to be a good steward of a community's resources."

EPRI Research to Support Indoor Farming

EPRI is deploying numerous 320 square-foot container farms around the country in collaboration with utilities such as the New York Power Authority (NYPA), Missouri River Energy Services (MRES), Great River Energy (GRE), Los Angeles Department of Water and Power (LADWP), Exelon, Tri State, American Electric Power (AEP), Seminole Electric, and Tennessee Valley Authority (TVA). Several other utilities are currently considering deploying container farms.

As these sites become fully operational in 2021 and beyond, EPRI will monitor their energy and water consumption. The data is expected to yield insights on how various operational models impact performance, how outdoor weather conditions impact resource consumption, and how facilities can affect grid operations and support sustainability. Preliminary findings are expected by this summer.

Project results can help indoor agriculture companies, utilities, economic development agencies, and other stakeholders better understand ideal siting conditions and grid infrastructure upgrades that may be needed. "We are also looking at how these facilities can potentially lead to educational and employment opportunities and benefit communities," said Sharp.

For instance, South Dakota State University has partnered with Missouri River Energy Services so that the indoor farm can be used for educational purposes and the produce can be distributed to the Children's Museum of South Dakota. Similarly, University of Tennessee professors and students are cultivating crops in the TVA container, and the vegetables are donated to a local food bank. A food bank is operating the NYPA farm in Buffalo, New York.

"Each utility is interested in examining similar issues of broad significance—such as the efficient use of energy and water and long-term sustainability," said Sharp. "At the same time, they are focusing on questions specific to their service areas, such as grid impacts, community impacts, and educational opportunities." said Sharp.

For more details on EPRI research on indoor agriculture, contact EPRI's Frank Sharp (fsharp@epri.com, 865-218-8055).

Electrification in the News

As reported in Utility Dive, Colorado regulators approved Xcel Energy's $110-million transportation electrification plan, with 15% of the budget focused on equity-related programs.

The New York Times reports on an ambitious initiative to retrofit, electrify, and decarbonize existing buildings in New York City.

As reported in E&E News, GM plans to spend an additional $7 billion on EVs and autonomous vehicles by 2025 and appoint a new chief EV officer.

Bloomberg reports on the challenges of making indoor agriculture cost-effective.

The New York Times reports on research which found that lifetime costs of EVs are lower than those for gas-powered cars.

Scientific American reports that California is planning to tighten rules in the state's building code on the use of natural gas for home heating and hot water.

Reuters reports on Apple's efforts to develop autonomous EVs that include its own battery technology.

The New York Times reports on the growth of companies that make electric delivery trucks and vans.

As reported in AP, Zoox, a company acquired by Amazon, has unveiled an autonomous electric taxi.

E&E News reports on initiatives to deploy electric delivery bikes by big companies such as UPS, Amazon, and DHL.

As reported in Reuters, Apple and ChargePoint will work together on integrating EV charging information (such as the location and status of charging stations) in Apple's CarPlay infotainment system.

As reported in Reuters, German grid operators 50Hertz and Stromnetz Berlin are working with subsidiaries of Volkswagen and Bosch to study how EV batteries can help stabilize the grid.

Upcoming Events

Note: Check the event websites for the latest updates on rescheduling due to COVID-19.

ASHRAE Virtual Winter Conference, February 9-11, 2021.

The International Energy Agency Heat Pump Conference, April 26-29, 2021, Jeju, South Korea (hybrid event, in-person and virtual).

EPRI's Electrification Events, May and June 2021.

Indoor Ag-Con, May 16-18, 2021, Las Vegas, Nevada.

Forth Roadmap Conference, June 14-16, 2021 (virtual event).

IEEE Transportation Electrification Conference and Expo, June 23-25, Chicago, Illinois.

Energy Storage North America, July 14-16, 2021, Long Beach, California.

Future Mobility Detroit, September 8-9, 2021, Dearborn, Michigan.

Electric and Hybrid Vehicle Technology Expo, September 14-16, 2021, Novi, Michigan.

Getting to Zero Forum, October 27-29, 2021, New York City.

EPRI Resources

Electric Vehicle Supply Equipment Criteria, January 2021.

A Review of Electric Vehicle Infrastructure Reports for North America: Best Practices and Lessons Learned, December 2020.

Load Shapes for Residential Variable Capacity Space Heating and Cooling, December 2020.

Heat Pump Water Heaters for Residential Use: Laboratory Evaluation of a 40 Gallon Integrated Unit, December 2020.

Customer Propensity for Electric Vehicle Adoption, December 2020.

Sustainability and Electrification: An EPRI White Paper, December 2020.

Electrification Opportunities in Military Installations, December 2020.

Electrification Opportunities in Municipal, University, Schools, Hospitals (MUSH) Market, December 2020.

Building Decarbonization and Electrification from the Customer Lens, December 2020.

Light-Duty Electric Vehicle Market Projections: Scenarios and Impacts, December 2020.

About EPRI's Efficient Electrification Initiative

In developed economies, electrification refers to the expanded use of electricity. This may involve powering new uses (such as cellular phones, computers, and server farms) or switching everyday technologies (such as automobiles, forklifts, and furnaces) from direct combustion of fossil fuels to electricity. Electrification offers potential to transform utilities and other industries in which power is a key input. As the electric supply becomes cleaner, electrification can reduce society's overall emissions. It can also lower costs and energy use for utility customers and improve economic efficiency, water use efficiency, grid utilization efficiency, productivity, indoor environments, and safety. Through collaborative research, development, and demonstration, EPRI's Efficient Electrification initiative is examining the impacts and technical aspects of electrifying the end use of energy—where it is more efficient to do so—for the benefit of customers, the environment, and society.

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