EPRI JOURNAL

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Solar Sheep

How grazing sheep can reduce vegetation management costs and bolster community support for solar projects

By Chris Warren

Over the past decade and a half, Aron Patrick has had a singular career focus: to expand the deployment of solar and other renewable energy generation. For nearly seven years, Patrick worked as assistant director and manager of renewable energy in Kentucky's Department of Energy. He then held various positions at the utility Louisville Gas & Electric and Kentucky Utilities (LG&E-KU) for nearly seven years before joining PPL Corporation, LG&E-KU's parent company, as director of research and development in the summer of 2022.

Patrick's wide-ranging experience deploying solar projects has taught him a lot about the barriers that need to be overcome to get more solar projects built. "Right now, the greatest single challenge we have to expanding solar generation in Kentucky is the problem of more land," Patrick said. "There are local communities that are opposed to using land for renewable energy."

In some cases, the opposition is the result of past solar projects that have had a negative impact on local ecosystems. For instance, Patrick has seen instances when developers have cut down forestland for a solar site and then laid down gravel and sprayed chemicals to reduce the need for vegetation management.

From a purely financial perspective, there is a rationale for this approach. Vegetation management is a significant operations and maintenance (O&M) expense. But solar and other renewable energy projects in Kentucky and around the country need community support to get built.

"At a minimum, these projects need to integrate with the natural environment and leave it no worse than it was before," Patrick said. "But what we really need to do is integrate these solar sites so that they improve the ecosystem and fit into the agricultural heritage our ratepayers expect. It's taking a solar farm from being potentially harmful to the environment to something that is beneficial and beautiful to look at."

A GRAZING SOLUTION?

In Kentucky and around the globe, an emerging answer to both address community concerns and reduce vegetation management costs has four legs and eats all day: sheep. While still at LG&E-KU, Patrick collaborated with EPRI to develop and implement a plan for sheep to graze 10 acres of a 50-acre solar farm in Mercer County, Kentucky. The demonstration project began in 2020, and a detailed description of the grazing plan and results can be found in the EPRI report, *Solar Grazing: Viability of Grazing Sheep for Vegetation Management, Year 2*.

For Patrick, the potential to reduce O&M expenses was made clear on a visit to a solar farm. "I was out at a site and noticed we had 30-plus people weeding underneath the panels," Patrick said. "This was labor-intensive and also a safety issue because you have low-trained workers on the property who could potentially weed eat a wire." LG&E-KU estimated the cost for the traditional mowing and weed eating to manage 10 acres of the solar farm was $14,000 in 2020.

While containing costs is important, the potential benefits of using sheep for vegetation management also include an improved local ecosystem. For example, a well-designed seeding and grazing plan for sheep will prevent most vegetation from growing taller than the panels and negatively impacting energy production. A sustainable grazing plan can also reduce water runoff, improve water and soil quality, and enhance regional biodiversity.

But all those potential benefits hinge on sheep being a practical solution for vegetation management. And that's what LG&E-KU and EPRI set out to learn in the demonstration project.

"We were worried about the safety and welfare of the animals," Patrick said. "We had accounting questions and legal questions. Are sheep a capital or O&M expense? We also had questions about whether the sheep would get away. I think people imagined this chaotic environment of sheep running around and our staff chasing them."

CHOOSING SHEEP AND CREATING A GRAZING PLAN

To begin answering these questions, a selection of Shetland and Katahdin sheep were brought to the solar site from nearby Shaker Village—a local non-profit that preserves the architecture and ways of the Shakers who moved to the area in the 1800s—to graze from the early spring to late fall of both 2020 and 2021. The breeds of sheep were selected because they were believed to be least likely to damage the solar panels and equipment.

One reason that is the case is that Shetland sheep are relatively small, which is an advantage in reaching vegetation growing under and around panels as low as 36 inches off the ground. The breed's small stature enables the animals to navigate around the panels and equipment without getting caught up in wires and other infrastructure. Larger Katahdin sheep were added later to help manage taller vegetation, like the invasive species Johnson grass.

The grazing plan developed for LG&E-KU by Shaker Village evaluated the optimal number of sheep to use and how often to rotate the animals on and off the land. Typically, a 10-acre pasture where sheep don't rotate would require about 20 animals. In this case, though, it was a priority to keep vegetation from growing taller than the lower edge of the panels to prevent panel shading and use rotational grazing. Rotational grazing is a type of regenerative grazing that provides a range of ecological benefits, from improving soil health to reducing soil erosion. It's also important to note that the intention was always to evolve and change the original grazing plan based on environmental conditions. Flexibility in

devising and adapting the grazing plan promotes the health of the sheep while meeting the solar site's vegetation management goals.

With that in mind, LG&E-KU installed nine one-acre paddocks that 25 sheep would rotate through. Another element of the grazing plan was determining how long sheep would graze in a paddock before allowing the vegetation to regenerate. This matters both for the sheep and the plants. Short grazing intervals followed by a restoration period allows the plants to keep growing and ensures that animals benefit from more palatable and nutritious vegetation. The grazing plan initially included five days of grazing followed by 45 days of recovery, which is the same approach used in the Shaker Village's pastures.

LESSONS LEARNED LEAD TO CHANGES

After the first grazing season, LG&E-KU and EPRI made several adjustments for 2021. The grazing plan was also adjusted to move away from a uniform five days of grazing followed by 45 days of regeneration. This was done better to match the natural seasonal variation in vegetation growth.

For example, cooler early spring temperatures mean plants grow slower, and fewer sheep are needed to control vegetation. As temperatures and vegetation growth rates increased, more sheep were grazed. For example, 18 sheep grazed for seven days in the early spring, followed by 63 days of recovery. From late spring through the summer, 51 sheep grazed for three days, followed by 27 days of recovery.

According to Dr. Ashley Bennett, an environmental research scientist at EPRI, who worked closely with LG&E-KU to implement the demonstration project, one takeaway from the first two years of grazing was basic but important. Sheep can be an effective vegetation management solution.

Not only were concerns that sheep would cause chaos and damage equipment unfounded, the animals reduced the utility's vegetation management costs. Indeed, the cost to use sheep in the project's first year was about $11,500, compared to $14,000 using mowers and weed eaters. In the project's second year, vegetation management costs were reduced to about $9,000 thanks to an improved grazing plan.

A NATIONAL SOLUTION FOR BETTER VEGETATION MANAGEMENT AND COMMUNITY SUPPORT?

LG&E-KU participated in the demonstration project because it wanted to serve as a model for other utilities considering grazing as a vegetation management solution. An upcoming EPRI report, *Evaluating opportunities for sheep grazing at utility-scale solar farms in the United States: A Review,* is expected to be published in 2023 and chronicles the challenges, opportunities, and practical application of agrivoltaics, specifically grazing, around the nation.

Agrivoltaics refers to the dual use of land for solar energy and agricultural production. Besides grazing livestock to manage vegetation, agrivoltaics can also include habitat conservation, especially for pollinators, as well as crop production in and around solar projects. Utilizing solar sites for multiple uses can bolster community support.

"From the landowner and community standpoint, land stewardship is a favorable aspect of agrivoltaics," said Terry Jennings, an EPRI principal project manager whose research focuses on advancing economically and environmentally responsible renewable energy development. "Local communities may be more supportive if they perceive the solar operator and landowner as good stewards of the land. Another aspect is continued agricultural usage that helps to maintain the agricultural heritage of a site or community."

Agrivoltaic applications like solar grazing are gaining interest and deployment. For example, the American Solar Grazing Association (AGSA) was founded in 2019 and had over 500 members by 2022. AGSA estimates that 15,000 acres of solar installations representing 2,500 megawatts are currently using animals to control vegetation.

But there are still challenges, including variable and uncertain costs. Solar developers are incentivized to build their projects as quickly, cheaply, and profitably as possible. Utilities are keen to reduce O&M costs but also are motivated by sustainability. "Many of our utilities are very interested in conservation and how solar sites can provide environmental benefits," Bennett said. "But the utilities also must have a business case to make changes, such as using a native seed mix to support pollinators instead of a non-native turf grass mix. They need to show modifications to current practices will not increase their costs and will provide ecological benefits."

BARRIERS TO IMPLEMENTATION AND MORE RESEARCH NEEDED

While there is genuine interest in solar grazing, EPRI's report also identified several barriers and areas that require additional research. Perhaps the most significant obstacle is an insufficient number of sheep and shepherds. Already, there are not enough sheep to graze the solar plants in operation across the U.S., let alone to manage vegetation at the many solar sites that will be built in the future.

Another barrier to more widespread solar grazing is the need for additional infrastructure at solar plants, including water for sheep to drink. Strong communication between solar power plant owners, operators, and sheep grazers is also important to develop and evolve grazing plans. It's also true that not all solar sites will be suitable for sheep grazing.

EPRI's report also notes that grazing sheep to manage vegetation at solar plants is still in its infancy, and much more needs to be learned. For example, more experience is needed to develop guidelines and best practices for successfully using sheep in vegetation management across different geographies and ecosystems. This includes learning how to combine pollinator habitat and grazing on the same site to integrate multiple ecological benefits. For now, the optimal approach for utilities and developers considering solar grazing is to work with experts to develop a grazing plan and to pilot it on a small parcel of land to test whether it can work and is cost-effective.

THE IMPORTANCE OF PATIENCE

At LG&E-KU, the initial experience of using sheep for vegetation management has been successful enough to expand the practice to a second, much larger solar farm near Harrodsburg, Kentucky. "We're planning ten 1,500-acre solar farms in the next few years, and there's no question moving forward how we are going to manage the land at our solar sites," Patrick said. "I can't imagine a situation where you wouldn't want sheep in some way."

But Patrick is also quick to point out that the utility's approach is evolving with the lessons it's learning. For example, LG&E-KU has even lowered its vegetation management costs by embracing technology—like motion detectors and security cameras—to monitor sheep. This has reduced the need for shepherds always to be on-site, a significant cost savings because labor is the largest expense of using sheep for vegetation management.

Patrick says another big lesson for anyone thinking about solar grazing is to understand it takes time. "This is not something where you can have one employee get it done quickly and expect it all done in a month," Patrick said. "We spent about a year planning and then two years in site prep. But that time is well spent when you see how beautiful these sites can be and how much they benefit local communities."

EPRI TECHNICAL EXPERT

Ashley Bennett

Going in Circles

Why a circular economy is so important to a sustainable electric power industry

By Chris Warren

Since the Industrial Revolution, economic activity around the globe has operated basically this way: Natural resources are extracted from the earth and then processed into goods that people purchase, use, and eventually throw away. It's a model that has vastly improved the living conditions of billions of people across generations.

As the name implies, circular economies represent a paradigm shift from the make-take-dispose model that has predominated since the 18th century.

Instead of disposing of products in a landfill, circular economies embrace a full life-cycle approach that starts with how products are designed and the resources used to make them. This approach can

processes that ultimately result in entirely new products. Circular economies also generate significant economic opportunities and have the potential to promote environmental justice, social include extracting usable materials from existing products or materials that would otherwise be wasted and feeding them back into manufacturing justice, and economic mobility, especially in communities that have suffered most from the linear model of economic activity.

The linear make-take-dispose model is not sustainable.

27B vs 92B tons

The annual extraction of natural resources required to make the global economy function rose from about 27 billion tons in 1970 to 92 billion tons in 2017, according to the Circularity Gap Reporting Initiative.

1.75 faster

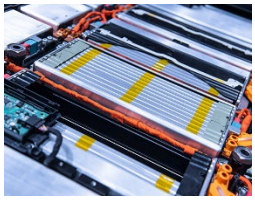
Humanity today uses resources 1.75 times faster than the Earth can replenish them and the demands on the natural world are only accelerating.

9.6B people

According to the United Nations, the expected global population of 9.6 billion in 2050 will require the equivalent of three planets' worth of resources.
It's likely impractical that humanity will be able to harvest significant resources on other planets for use on Earth—which is why interest in circular economies is increasing.

EXPLORATION IDEAS

REPURPOSING WIND TURBINE BLADES: One idea being explored is repurposing glass fiber wind turbine blades for cement co-processing. After wind turbine blades are removed from service and reduced to an appropriate size, the material can be used as an alternative fuel and raw materials for producing Portland cement. This application eliminates solid waste and reduces greenhouse gases associated with cement manufacturing.



EV BATTERY REPURPOSING: As the number of EVs increases, the opportunities for battery repurposing in stationary applications multiply. According to an estimate by McKinsey & Company, the supply of EV batteries that can be used for stationary storage could surpass 200 GWh annually by 2030. This approach takes advantage of the substantial value retained by electric vehicle (EV) batteries after they are no longer suited for powering automobiles. By some estimates, used lithium-ion EV batteries retain 80 percent of their original capacity and all the embedded energy of their manufacture. With specific software controls and integration, those used EV batteries can have a second life as stationary energy storage systems. Performance testing, hazard assessments, and warranty and liability R&D are underway now to determine feasibility.

PV MODULE RECYCLING: The first commercial recycling plants with advanced treatments to separate materials are being planned and constructed to support the growing supply of end-of-life solar modules. Innovative recycling processes being tested at a pilot scale may offer enhanced recycling quality and compete with landfill disposal prices in the future. The National Renewable Energy Laboratory (NREL) estimates that between 25 and 30 percent of all silver, aluminum, and silicon used in the solar industry could be supplied by recycled modules after 2040.

EXTENDING THE USEFUL LIFE OF PRODUCTS: There is economic value in rethinking everything about products, from designing them to making recycling and reuse easier to extending their useful life. Understanding this value is not just about sustainability. It is also about developing new business models, such as product-as-a-service and sharing platforms that give people access to products when they need them through a subscription instead of an outright purchase.

MITIGATING SUPPLY CHAIN RISKS: Pursuing circularity can also mitigate risk. For example, supply chain bottlenecks have slowed and canceled projects in recent years due to increased costs and a lack of products and materials. But what happens to those project risks when companies can take advantage of local supply chains of recycled and reused equipment and materials rather than depending on imports? One example of this approach is extending the life of transformers or refurbishing and redeploying them in new facilities. Another risk mitigation benefit is reducing dependency on foreign nations controlling critical materials. While pricing is a significant risk, so too are human rights violations. The U.S., European Union, and China have actively made significant federal investments in recycling infrastructure to extract, purify and reuse materials such as lithium, cobalt, and nickel in new lithium-ion battery manufacture.

SUSTAINABILITY GOALS: Long-term environmental and sustainability goals at the federal level are also driving a transition toward circular economies. For example, in March 2020, the European Commission released a circular economy action plan. The plan lays out strategies and policies for eliminating waste and bolstering biodiversity while also achieving Europe's 2050 net zero carbon emissions target. In the United States, the 2021 Bipartisan Infrastructure Law allocated nearly $7 billion for new and expanded commercial-scale processing, manufacturing, and recycling facilities.

DEFINING CIRCULARITY IN THE ELECTRIC POWER INDUSTRY

Circular economy concepts are highly relevant to the electric power industry and often are related to existing sustainability goals and priorities. For example, reductions in greenhouse gas emissions and the transition to decarbonized electricity depend on a shift to greater use of renewables, energy storage, and other low-carbon technologies. The industry also procures and uses huge volumes of materials and equipment and manages what happens to them at the end of their useful life.

In 2021, EPRI formed the Circular Economies for Energy Technologies Interest Group to bring together utilities and other stakeholders to share information and experiences and identify new research initiatives to help companies incorporate circularity across their entire organization.

"We started with a definition of circularity which goes beyond recycling and reuse to thinking about a larger range of aspects through the whole life cycle, such as designing-for-circularity and life extension," said Stephanie Shaw, an EPRI technical executive who leads the interest group. "We began with a focus on solar, wind, and battery technologies, but we also received many inquiries around equipment like transformers as well as coal combustion products, for which the industry is already participating in circularity activities."

In the past, the European Union, the Organisation for Economic Cooperation and Development, and the Ellen MacArthur Foundation have all developed circular economy policy frameworks. EPRI reviewed these and other frameworks and interviewed a wide range of subject matter experts to produce the report *A Framework for the Application of Global Circular Economy Principles for the Electric Power Industry*.

Although there is plenty of overlap with other frameworks, EPRI researchers determined that a circular economy in the electric power industry has three fundamental components:

- **Lowering the use of natural resources:** This includes transitioning from extracting and burning coal and other fossil fuels to produce electricity and relying more on renewable generation sources like solar and wind. Bolstering energy efficiency and expanding end-use electrification (particularly when renewables provide electricity) also help to reduce the consumption of natural resources to supply society with the electricity it needs.
- **Extending equipment life:** Purchasing and installing new equipment is necessary less frequently when existing equipment operates reliably and effectively. The lifetime of all equipment used to produce and distribute electricity can be extended by manufacturing more durable products designed to be easily upgraded or repaired. Repair or refurbishment can sometimes add years to project lifetimes, delaying the need for end-of-life management.
- **Eliminating resource loss:** Even the most durable equipment eventually ends its useful life. A circular economy approach anticipates that end of life and establishes systems and processes to reuse, repurpose, and recycle as many materials, components, and byproducts as possible. For example, solar modules and wind turbines typically operate for 20 to 30 years. Lithium-ion battery modules are expected to last 10-20 years, depending on their application. At the end of their life, supply chains must be in place to collect and extract materials from what will be a large volume of equipment to manufacture new turbines and modules. NREL estimates the total value of recyclable materials in end-of-life solar modules will be $15 billion by 2050. These materials would be enough to manufacture about 2 billion new modules (approximately 630 GW capacity).

RESEARCH TO IMPROVE CIRCULAR ECONOMY EFFORTS

In 2022, EPRI's interest group hosted a series of webinars and conducted several technical assessments related to circular economy concepts in the electric power industry. "Last year was about gathering examples of how companies are implementing circular economy practices in their business processes, as well as clarifying definitions and metrics, so we have a better sense of what this

means for the industry," Shaw said. "That meant addressing topics like design-for-circularity, life extension, procurement choices, and decommissioning to make recycling and reusing equipment and materials practical. We're raising awareness about a variety of concepts."

One webinar topic was current options for recycling wind turbines; today's primary option is reusing blade materials as input and fuel for producing Portland cement. Another webinar examined circularity potential in a broader range of energy technologies, including transmission and distribution equipment and nuclear generation equipment and materials.

The circularity potential of fuels was also considered. For example, coal combustion products have long been used to produce new products like wallboard and to replace Portland cement in concrete production. Emitted methane could be recovered for upgrade and use as renewable natural gas.

A webinar also examined the potential to refurbish and extend the life of transformers. Beyond any sustainability benefits, extending the life of transformers is currently a priority for many utilities because supply chain delays have led to multi-year waits to receive new equipment.

The EPRI report *Novel Battery Module Designs to Enhance Sustainability* delved into how design can help incentivize recycling and repurposing. For example, the global demand for EV batteries is expected to reach 1400 GWh annually by 2030. Lithium-ion batteries currently dominate the EV battery market. They are made with critical materials like cobalt, nickel, copper, graphite, and lithium, none of which is sourced in large quantities in the United States or Europe. Though the Inflation Reduction Act, passed in 2022, seeks to create domestic supply chains for lithium-ion batteries, more financially advantageous and efficient recycling and repurposing of used batteries could meet some of the demand for critical materials.

Currently, a lack of recycling facilities and the relatively small volume of EV batteries that have reached the end of their useful life limit the reuse of used batteries in similar applications (such as another vehicle) or repurposing them for use in other applications (such as stationary storage). But so too does battery module design, which today results in the need for a multi-step, labor-intensive process of disassembly and sorting before recycling. Recycling and repurposing are also hindered by the lack of standardization among EV and stationary battery packs and modules. Another impediment is the lack of performance and safety standards specifically associated with reused or repurposed batteries. Design that makes it faster and easier to sort and disassemble packs and modules could incentivize more circularity. One example is more comprehensive labeling of materials in a battery using color coding, bar codes, and radio frequency ID

tags (RFIDs). Clear labeling allows for rapid identification of hazardous materials and more efficient collection and sorting of materials for recycling and repurposing.

A CIRCULAR ECONOMY PIONEER

A significant benefit of joining EPRI's Circular Economies for Clean Energy Technologies Interest Group is the opportunity to learn from other companies, including those that have been engaged in this area for a long time. For example, Enel Group placed circular economy practices at the heart of its strategy in 2015 and directly connected circularity and achieving decarbonization and economic objectives.

"We decided to make a strategic shift and look at it as an accelerator of our business," said Peter Perrault, the director and head of circular economy at Enel North America. "Circular economy is critical for net zero; it's where the rubber meets the road. If you have scope 3 emissions reduction goals, you have to think about circular economy."

Over the past eight years, Enel has injected circular economy practices into all stages of its value chain, from design and engineering to procurement, construction, and O&M. Circularity is also a driver of the pace of and processes for decommissioning existing thermal power plants, which it owns or operates in various global regions, although not in North America. Circular practices also guide site selection and community engagement around new projects.

At this year's World Economic Forum in Switzerland, Enel launched a circularity index for economic performance, which evaluates the raw materials and fuels needed to achieve a company's revenue goals. At the same event, Enel announced a goal of reducing by half the resources used to achieve its revenue goals, with a target of 92 percent circularity by 2030.

Even though Enel has been pursuing circularity for nearly a decade, Perrault spends much of his time educating colleagues about what circular practices are and how they can be applied to their work inside Enel North America. "If you are a construction team going to the procurement group and someone talks about embodied carbon, they won't know how that relates to their role because their job is to build a power plant," Perrault said. "So that is the very first thing: education."

But Perrault's role also involves working with procurement to establish criteria for awarding contracts to ensure they align with the company's circular economy goals. He collaborates with the legal, finance, and marketing departments as well. "We work to understand contractually what we are responsible for versus what equipment and services providers are responsible for because they are purchasing materials," Perrault said. "And in marketing, we need to educate our customers about what we are doing and why. On any given day, I can work across many business lines and functional areas of the company."

Participation in the EPRI interest group gives Enel a forum to share what it has learned about implementing circular economy practices in the utility industry. But it's also beneficial in shaping Enel's future direction. "Working with EPRI is helpful and beneficial because we are able to share some of our ideas and vision and position," Perrault said. "But the research EPRI is doing also helps inform our future vision and supports the type of collaborative environment needed to create change."

EPRI TECHNICAL EXPERTS

Cara Libby, Fiona Baker, Ben Gallagher, Mitch Rencheck, Stephanie Shaw, Gabriella Siegfriend

How a Single Device Helps EVs Provide Cost-effective Backup Power to Homes

The Smart Power Integrated Node (SPIN) delivers backup power along with cost savings and grid support in one small box

By Chris Warren

In the summer of 2020, California's grid strained to keep up with demand for electricity during a scorching heat wave. In August of that year, rolling outages impacting hundreds of thousands of customers were initiated because not enough capacity was available to keep up with demand. The outages triggered the California Independent System Operator (CAISO), the California Public Utilities Commission (PUC), and the California Energy Commission (CEC) to issue a joint root cause analysis that found that extreme weather, market practices, and resource adequacy and planning processes combined to necessitate the power shutoffs.

At the individual household level, however, the experience of rolling blackouts and the potential for more triggered many people to investigate the potential for energy storage to provide backup power during outages. "What people are doing if they already have solar on the roof is to start to install storage," said Sunil Chhaya, an EPRI senior technology executive who leads electric vehicle (EV) and energy system integration efforts. "Solar companies do it now, and an income tax credit incentivizes it. So, when the lights go out, you can automatically switch over to storage."

Pairing rooftop solar with energy storage is a practical and reliable solution to deliver backup power during infrequent grid outages. But it's also a pricey solution that is well outside of the financial reach of many. For example, a typical behind-the-meter energy storage unit that provides about 10 kilowatt-hours of capacity – enough to deliver two to three hours of backup power to the typical home – costs about $15,000 to install.

But there's another potential backup power solution that may already be available to Californians and other Americans: the EV sitting in their driveway. "There are a lot more people who have EVs than have storage," Chhaya said. "So, the question is this:

can we use EV batteries that have 60, 80, or 100 kilowatt-hours and have already been paid for to provide backup power to the home?"

A NEW SPIN ON BIDIRECTIONAL CHARGING

There is no lack of research and discussion today about the future potential of EV batteries to provide backup power. But there are not yet any commercially available bidirectional chargers able to take electricity out of an EV battery and use it to provide backup power directly to a building. "Today, you can find vehicle-to-grid technology that only works when the grid is on," Chhaya said. "It doesn't work when the grid is off, and it only sends power from the vehicle to the grid, not to the home where it's needed."

But there is another potential solution for both tapping EV batteries for backup power and enabling EV owners to earn revenue for providing grid services and helping utilities reduce their peak load. Since 2016, EPRI has worked with Flex Power Control on developing and testing the Smart Power Integrated Node, or SPIN. SPIN is a single device with the intelligence to automatically manage a business or household's solar, EV, and stationary storage assets to achieve the building owner's priorities. For example, SPIN can automatically sense a power outage, instantly provide backup power, and send power back to the grid.

Each SPIN includes multi-port bidirectional inverters that connect both to the grid and to a home or business's solar, EV, and storage units. Each device also has a power routing matrix comprising multiple switches that connect each of the DERs and the grid in multiple configurations. Importantly, SPIN also has a brain in the form of control and coordination software that optimizes how each asset operates in grid-tied and standalone modes. Initially supported with EPRI Technology Innovation (TI) funding, SPIN has since received funding from the U.S. Department of Energy (DOE), the California Energy Commission (CEC), and the National Renewable Energy Laboratory (NREL).

For example, DOE funding supported the initial prototype development using commonly available electronic components. After demonstrating its ability to control power flow, Flex Power Control built a more sophisticated prototype that was then tested at DOE's Oak Ridge National Laboratory. There, the device was able to perform fast EV charging, dispatch an EV battery's electricity to the grid, and deliver backup power during an outage using rooftop solar and EV batteries.

Over the course of numerous projects with EPRI, DOE, and other researchers, SPIN has repeatedly demonstrated its functionality, including support for the grid. For example, in one study, the University of Kentucky researchers simulated a feeder with 70 houses. Each of the simulated houses included a 7-kilowatt solar system, a 10-kilowatt-hour energy storage system, an EV charger, and a SPIN to manage the DERs. SPIN was able to reduce the feeder's peak load by 42 percent. "Our initial challenge was to develop the technology, improve it, and show that it works and delivers value," said Greg Smith, a founder of Flex Power Control, who formerly worked as an engineer at General Motors. "We have proven the technology works and shown the potential value proposition."

HOW SPIN PROVIDES BACKUP POWER WITH MINIMAL EV BATTERY IMPACTS

EPRI summarized the research results funded by DOE and the CEC in the report *Battery Performance Assessment of Vehicle-to-Grid Capable Electric Vehicles: Testing Methodology and Experimental Results*. Among other things, the report confirms SPIN's ability to deliver backup power from an EV battery. The report also quantifies how much battery degradation would result when the battery-powered an EV and was used in a home.

To do that, researchers at NREL tested two 17-kilowatt-hour battery packs made by LG Chem that are used in Pacifica plug-in hybrid minivans. One of the batteries was charged and discharged three times each day for over 12 months to simulate an EV used for driving and delivering energy to a home. That translated into about 11.7 kilowatt-hours for transportation and 5 kilowatt-hours to the building. To compare the degradation impact of those vehicle-to-building discharges, the second battery was cycled an equal number of times daily for the same duration of time. But its discharges only simulated what was needed for driving.

By cycling the batteries three times per day, the NREL researchers were able to collect data representing about four years of operation. The test results showed that using the EV battery for typical driving and vehicle-to-building discharge had a small impact on battery degradation. For instance, the battery that provided energy for driving and a building had about 90 percent of its original capacity at the end of the testing period; by comparison, the driving-only battery had about 95 percent of its original capacity. Using these degradation rates, the researchers concluded that over 10 years, the driving-only battery would retain 82 percent of its original capacity. In contrast, the battery pulling double duty would have 77 percent of its capacity.

BENEFITS BEYOND BACKUP POWER

Clearly, an EV battery won't be called on daily to provide backup power to a home as power outages remain rare. But testing the battery as if it was being dispatched from the vehicle to a building daily also provided insights about the ability of a SPIN-managed EV to deliver additional benefits.

For example, the soon-to-be-published EPRI report includes an analysis of the potential bill savings that could come from using SPIN to shift EV charging to times when electricity rates are lowest. The potential annual bill savings for a residential customer were estimated to be almost $1200. Commercial customers using SPIN to manage charging could save over $2000 annually from lower energy costs and avoided demand charges.

The report also detailed a range of other utility, grid, and societal benefits EVs managed by SPIN can deliver. For example, 200 EVs equipped with bidirectional charging could reduce annual peak load by 750 kilowatts. By assuming an avoided cost of infrastructure of $25 per kilowatt, that would result in savings of more than $280,000 over 15 years.

Large numbers of EVs with bidirectional charging capabilities could also substantially reduce the amount of renewable energy that must be curtailed. According to EPRI, about 1500 gigawatt-hours of renewables were curtailed in 2020. But if 500,000 EVs were to charge when electricity prices are low in the late morning and late night and then discharge when demand and prices are high in the early morning and late afternoon, the curtailment would be far lower. According to EPRI's analysis, 332 gigawatt-hours would not need to be curtailed. A bill recently introduced to the California state legislature would mandate that all EVs sold in the state be bidirectional capable by model year 2027.

For utility customers – particularly those that have already purchased an EV and solar – integrating SPIN also promises to dramatically reduce the costs associated with securing backup power. By eliminating the need to install stationary storage and an inverter, SPIN can eliminate the $15,000 needed to purchase a 10-kilowatt-hour battery. In addition, with SPIN, there is no need for either a $1750 solar PV inverter or an EV charger. According to the EPRI report, these components cost $28,000, compared to the $7000 to purchase and install SPIN. EPRI will be publishing three more SPIN-related research papers in the next year.

THE ROAD AHEAD

Sunil Chhaya has been deeply involved in helping SPIN move through the many development and testing stages over the past seven years. He believes the device is ready to begin delivering benefits to utility customers, utilities, and the grid. "This is one step away from large-scale deployment," Chhaya said. "That's because it's a no-brainer. It removes a lot of hardware from the house needed for DERs. Especially for new construction, it's a no-brainer because you would just need to put it in as part of the electric panel."

For SPIN to move towards the large deployment Chhaya envisions, the next step is to receive Underwriters Laboratories (UL) certification. UL certification is expensive, and Flex Power Control is

currently seeking funding to achieve certification. “Certification is really about starting a production line because for certification to occur, it’s done with the products you are actually going to produce,” Smith said. “It’s really a product launch.”

Flex Power Control now has two versions of SPIN to simplify and speed up the certification and production process. The initial focus will be on the SPIN-EVO, a bidirectional charger that can provide backup power to a home during outages. For homes already equipped with PV or storage backup, EVO adds the EV backup component only. Its addition is akin to a retrofit.

The second version, SPIN-MPX, is a bidirectional charger but also integrates inverters for solar, stationary storage, and the EV and manages all the assets according to a customer’s priorities. The SPIN-MPX is more suitable for new construction or new installations because it removes the need for duplicative hardware and complexity. Instead of a separate EV charger and solar and storage inverter, new installations only require a single SPIN-MPX. Once certification is secured, Smith says SPIN devices will be available to customers through a distributor able to install and service the device.

As Flex Power Control continues to pursue the funding needed to become UL certified, the company is also actively pursuing opportunities to collaborate with utilities on pilot projects. One of the main reasons to engage with utilities is to elevate awareness about how SPIN functions and what benefits it can provide. “We want to get people to experience it so that they know it is what we say it is,” Smith said. “We would first want to work with utilities in their own lab because we think it’s important for them to get comfortable with it. Then we would want to do a field pilot with a limited number of customers to help determine the best use for the device at their location.”

EPRI TECHNICAL EXPERT

Sunil M. Chhaya, PhD

About EPRI

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

Together, we are shaping the future of energy.

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