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Solar+Storage: The Start

The first of a three-part series

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VOLUME 1 | ISSUE 1 | APRIL 2020

Renewable solar and batteries combine to provide reliable, economically viable energy at utility scale

Introduction

When Thomas Edison founded a research lab in Menlo Park, New Jersey, in 1876, he brought experts together to make practical change in the world. For him, contemporary needs were too complex, the problems too wide-ranging and the understood science too deep for any single person. At the time, collecting experts to work together was innovative. Since then, it has become a central theme of modern invention.

The 21st century's environment is even more complicated. Addressing today's technological challenges – space discovery, disease, quantum computing and climate change, for example – relies on many kinds of specialists, including lab scientists, entrepreneurs, public policy experts, engineers, builders and communicators. Many would say it takes not only teams of people, but teams of organizations, each bringing its strengths and perspectives to a problem.

Especially when the problem is as complicated and varied as providing energy to a modern city. This is happening in San Antonio, Texas, as experts collaborate across fields and institutions to address a pressing, close-to-home problem: how to combine renewables and batteries for reliable, reasonably priced energy at a level and scale large enough to supply the utility serving the seventh-largest city in the United States. What they are finding stands to contribute to a quiet yet clear energy evolution in the years to come.

Today's energy environment is complex, with multiple local, state, national and international stakeholders pressing to advance different goals.

Today's Energy Context

Today's energy environment is complex, with multiple local, state, national and international stakeholders pressing to advance different goals. An electrical utility must navigate these landscapes expertly to succeed. Here are some fundamental aspects of today's energy scene:

Rapid technological change: Modern technologies that supply and use power hurtle from brainstorm to workable prototype. From the perspective of customer demand for power, known as "load," many customer devices and appliances are increasingly

efficient. A good example is the quick progression from incandescent bulbs to fluorescents to LEDs. As devices become progressively smarter and connected, they make better use of energy resources. And as providers gain access to data related to energy use, they can better manage and plan for future needs. Greater electrical efficiency and decreasing customer demand have helped utilities defer new power plant construction, even with increasing populations.

Evolving societal preferences: For environmental, economic and political reasons, Americans have grown more supportive of renewables in recent years. Individual consumers, organizations and entire markets see the benefits of low-cost renewable energy sources and are embracing them at higher rates. At the same time, there remains low consumer tolerance for unreliable power or high prices.

Shifts in available resources: Evolving technologies have made domestic fossil fuel resources cheaper and more available, providing reliable fuel for large, traditional electrical generation power plants. Even so, fossil fuels' supremacy has made room for other sources. Solar, wind and emerging renewables have improved in their generation abilities and become less expensive. Meanwhile, fossil fuels, particularly natural gas, still dominate in states where cost remains low.

The Challenge

The appeal of renewables is obvious – clean, abundant power. The challenge, though, is that the two most viable sources of renewable energy, wind and solar, are intermittent. This wouldn't be a problem…except that customers expect electricity to flow when they flip the switch, even if it's dark outside and there's no breeze.

Many experts believe improvements in large-scale battery technology can mitigate this weakness – and San Antonio, Texas, is an excellent test bed for verifying that hypothesis. With its low latitude and mostly clear weather, San Antonio has great sun exposure. At the same time, it uses lots of electricity. San Antonians use the same appliances and gadgets as other Americans, but the overall energy load on the system increases to peak levels when air conditioners cool a growing population during long, hot summers.

On a normal day, San Antonio is like most cities: solar energy production begins in the morning, peaks in the afternoon, and falls off in the evening. Also like most cities, energy use peaks in the afternoon and evening, when people return from work or school and turn on their A/Cs, use their appliances and watch TV. San Antonio is a typical city: its solar panels can't generate maximum electricity when it's really needed.

If large-scale batteries can save enough energy for several hours, however, they can overcome this lag between solar production and energy use – and increase renewables' meaningful contribution to

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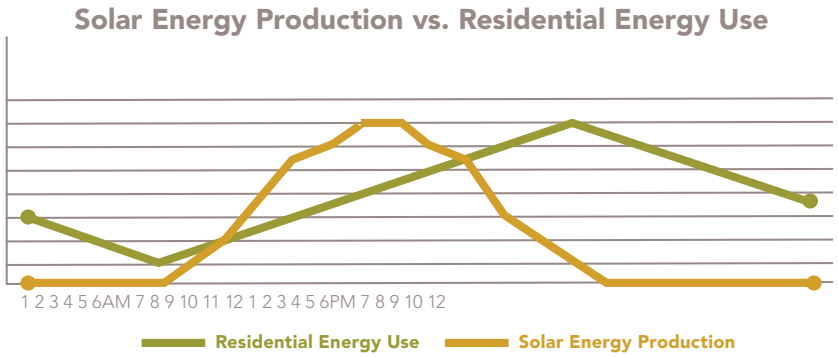

an energy portfolio in a way that is also financially viable for the utility and its customers. Other methods of combining solar power and storage also hold promise. How these technologies interact in practice is not yet well-understood, which made pairing them in a large-scale project and applying them in practice especially appealing to three entities – CPS Energy, Southwest Research Institute (SwRI) and Renewable Energy Systems (RES).

The result of their collaboration is Solar+Storage, a research project that will not only add to the understanding of solar energy and battery storage, but does it while functioning on an actual grid. The success of this project has the potential to bring a promising idea into mainstream use nationally and globally.

The Players

▶ CPS Energy: Municipally owned utility for the City of San Antonio, seventh-largest city in the nation

- Serves more than 800,000 electric customers over a 1,514-square-mile service area with more than 3,000 employees
- Participates in an electricity grid interconnected to the rest of Texas and administered by the Electric Reliability Council of Texas (ERCOT)
- Boasts a history of embracing renewables as part of its Flexible Path initiative to balance legacy power generation with renewables

cpsenergy.com

▶ Southwest Research Institute (SwRI): San Antonio-based independent nonprofit focused on advanced science and applied technology

- Employs more than 2,700 scientists, engineers and support staff
- Conducts research and provides engineering services to domestic and international clients in the commercial and government sectors
- Consists of ten divisions that focus on widely diverse areas of applied science (including mechanical engineering, space science, intelligent systems, applied chemistry and nuclear waste regulatory analysis) and collaborate across disciplines to answer complex technical challenges

swri.org

▶ Renewable Energy Systems (RES): World's largest independent renewable energy company

- Developed and/or constructed over 17 GW of renewable energy projects across the globe
- Active in onshore and offshore wind, solar, energy storage and transmission and distribution
- Employs over 2,000 people and operates in 10 countries

res-group.com

The Project

Solar+Storage combines two technologies: a solar farm (5 MW AC) and an adjacent battery energy storage system (10 MWh). Located on about 50 acres inside San Antonio, almost 18,000 dual-axis, monofacial solar panels (with cells on one side of the panel) transform sunlight into electricity – enough to power about 1,000 homes.

Organized in racks, the batteries are separated into four independently cooled units, each approximately the size of a shipping container. The solar array and batteries connect to the CPS Energy power distribution grid in parallel and interact with it independently, which gives researchers flexibility as they discover how to optimize the technology in practice.

Co-located with the main project is a smaller testbed containing solar and storage components with some important modifications. A portion of these solar arrays are bifacial, with cells on both sides of the panel to receive direct sunlight from above, as well as light reflected off the ground below. They feature more meters, allowing researchers to measure how ground coverings and other environmental characteristics affect generation. Untethered from the main project, it also admits easy modification to test new ideas on a small scale.

The Process

As with many leaps in technology, this story begins with a conversation. When CPS Energy then-CEO Doyle Beneby heard a conference presentation on energy storage, he wanted to know more. He engaged a consultancy to research the possibilities, and the resulting feasibility study described multiple opportunities for using batteries.

CPS leadership reasoned they could be feasible, says Lonny Ahr, Business & Economic Development manager at CPS Energy, "so we decided to stick our toe in the water." About the same time, the Texas Commission on Environmental Quality (TCEQ) issued a Request for Grant Applications under its 2016 New Technology Implementation Grant Program.

CPS Energy won a $3 million award and began to fill in the details for moving forward. Early in the process, Ahr and David Jungman, senior director of Business & Economic Development for CPS Energy, met with SwRI CEO Adam Hamilton. Conversation moved to the topic of combining solar and storage, and Hamilton was interested. As a member of the SwRI Board of Directors, former CPS Energy CEO Milton Lee had also advocated for a cooperative project between the two entities. Perhaps, some thought, this could be it.

Solar+Storage combines two technologies: a solar farm and an adjacent battery energy storage system.

Conversations progressed under the leadership of current CPS Energy President and CEO Paula Gold-Williams. SwRI had an available plot just the right size – about 50 acres – in a hard-to-miss highway location that would attract public interest. Arrangements were made for a 25-year lease at a reasonable rate, with agreements between the two organizations for data sharing and other details.

As CPS Energy released a Request for Proposals to outsource the design, engineering and construction, it conducted in-depth planning and coordination with SwRI. "Everyone was involved," says Ahr, "including operations, accounting, legal, corporate communications, safety…the list goes on."

A detailed selection process considered more than 20 respondents and awarded the contract to Renewable Energy Systems (RES). Detailed efforts followed, from planning through construction. The facility required considerable work with the City of San Antonio, including securing permits, ensuring environmental compliance, and cooperating with the San Antonio Fire Department on its safety requirements. RES worked closely with CPS Energy and SwRI to perform the engineering, design, procurement, permitting and construction of Solar+Storage.

As with any complex operation, collaborations resulted in changes to the original plan. At the start, SwRI and CPS Energy had expected to place the batteries in an existing building that currently houses SwRI's battery test facility. During the planning process, however, RES raised concerns about how to improve safety. The final design, now built, keeps the four battery enclosures away from the main building, separated by a parking lot. With $3 million in TCEQ financial support, CPS Energy funded the project cost of approximately $16 million.

Throughout the entire process, CPS Energy, SwRI and RES have found excellent partners in each other, and that relationship will continue. During the first five years of operations, CPS Energy is mandated by the TCEQ grant to submit annual operation status reports. These reports will be made publicly available on an informational website.

The Promise

For CPS Energy, SwRI and RES (sometimes called "the three amigos" behind the scenes), close coordination and collegiality have been hallmarks of the project. While they have worked closely to design, construct and operate it, they have very different (though compatible) hopes for what they'll glean.

CPS Energy. "We had been very coal heavy, but we've been in the process of transforming the utility," says CPS Energy COO Cris Eugster. In recent years, CPS Energy has rolled out forward-looking initiatives, including its ***Flexible Path*** framework (which infuses new modes of generation into a traditional mix) and ***Save for Tomorrow***

Energy Plan (STEP) program to reduce the community's electrical requirements. "About five years ago, we started talking a lot about energy storage," Eugster adds. "We knew if you could pair renewables with storage, you could follow the demand curve [which shows how a city's electricity use peaks in the afternoon, and plummets at night] in a better way. That's the holy grail in terms of moving beyond traditional power plants."

That holy grail is often called ***solar shifting***, the ability to overcome the fact that solar generation maxes out in early afternoon, but electricity demand reaches its height hours later, as people return home from work and school. Storing the energy from peak generation for use during peak demand would reduce the need for fossil fuels, which typically fill the gap. This could prove especially important in the San Antonio market, which saw record demand in summer 2019 due to triple-digit temperatures.

In addition to solar shifting, Solar+Storage will explore other ways to combine solar and storage. For example, the Electric Reliability Council of Texas (ERCOT – Texas' electric grid manager) pays providers to help maintain a grid frequency of 60 Hz, which keeps machines and electronics safe. "The beauty of batteries is that they can both add electricity or take it away, which makes them a unique asset on the grid," says James Boston, CPS Energy's manager of market intelligence. And they can do it quickly, he adds: "Batteries can respond within milliseconds to maintain grid frequency." This model, called fast responding regulation service (FRRS), is an ancillary service ERCOT pays for, and represents a potential revenue stream worthy of exploring.

There are other applications of Solar+Storage, too. One example is the ability to change customer prices according to scarcity, so that electricity "goes on sale" when there is plenty available and gets more expensive when there's not. Another potential use is as reserve capacity, replacing more expensive, slower-responding turbines. Which application or mix of applications is optimal – in terms of economic benefit, grid reliability and other factors – is something CPS Energy wants to find out.

CPS Energy has endorsed solar for years through purchase power agreements, where it buys solar power from a separate vendor that owns and operates the solar facility. This first foray as a solar owner represents new opportunities. According to CPS Energy's Senior Manager Power Plant Wayne Callender, learning how to operate a site will prepare the utility for adding more owned renewable assets to its portfolio. "We'll get important on-the-job training during the first five years, while RES provides operations

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and maintenance," he says. CPS Energy will discover what site upkeep requires in terms of electricians, welders and lawn-care personnel – and also how the jobs change when workers do their work at dispersed renewable energy sites, rather than at centralized plants.

CPS Energy aspires to be a leader for battery use throughout the ERCOT market. "For many reasons, Texas wants to get batteries into the market," Eugster says. But, he adds, "Batteries are different enough from other components of the grid that current methodologies need updates to account for them." With the insight it gleans through Solar+Storage, CPS Energy expects to contribute to those discussions.

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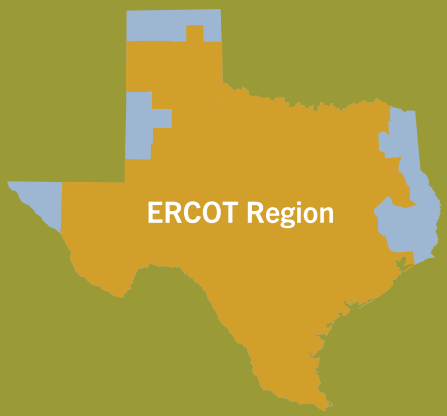

SwRI. SwRI is already well-known as a leader in battery research. It operates its own battery laboratory, where researchers test batteries in countless ways, including burning and puncturing them. As the leadership behind Energy Storage System Evaluation & Safety (ESSES), a battery technology consortium, SwRI conducts R&D for a collection of auto makers and others who want to gain understanding about the batteries used in hybrid and electric vehicles. This nonprofit research institution expects the Solar+Storage project to extend its considerable understanding of battery storage – to apply to its work with electric vehicles (EVs) as well as in other settings.

One goal is a better comprehension of the future of EV "fast charging." As more individuals, families and corporations buy more EVs, greater charging infrastructure must follow, and drivers will require fast and convenient charging. Questions abound about how batteries fit into that, according to Jayant V. Sarlashkar, institute engineer in SwRI's Automotive Propulsion Systems Department. "What are the best ways of DC fast charging?" he asks. "How can we charge from battery pack to another battery pack when the chemistries of each are different?" He foresees a future when gas stations generate electricity through solar panels, then store it in batteries to charge EVs. Experimentation with larger cells like the ones used in the Solar+Storage project will provide valuable insight.

SwRI has achieved industry leadership in small-scale battery research; now, Solar+Storage opens up larger-scale applications.

For example, the US Department of Energy has expressed interest in ***aggregation behind the meter***, a model that allows distributed, customer-owned resources to provide energy to the grid. These "customer side of the meter" systems accept a greater variety of electricity generating resources, distributed throughout a service area. It is easy to imagine businesses across a city signing up to get paid for their small contributions to the grid. "This project gives us the chance to explore the technical limits of distributed energy resources," says Terry Alger, director of SwRI's Automotive Propulsion Systems Department.

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As renewables assume a larger role in a utility's energy portfolio, other questions arise. One involves the reserves required to ensure service. Most of the year, backup generation capacity sits idle, awaiting the time it's needed (due to unusually high demand on a hot day or a suddenly offline power plant, for example). In these instances, it cranks up on command. That's easy to plan for with fossil fuel-fired turbines, which are well-understood sources of stored energy that don't degrade over time. As CPS Energy starts to depend more on battery storage supplied by renewable energy, reliability needs to be rethought, says Sarlashkar. "How much storage do I need as a safety factor to back up the renewable part of the grid?" he asks. "Is it a one-to-one ratio? Twenty percent? Or something else?" The answer depends on multiple factors, including battery degradation and the ratio of renewables to traditional fuel sources. SwRI's separate test bed allows researchers to pursue other questions about solar energy, energy storage and the two components taken together. On the topic of solar energy generation, SwRI researchers look forward to better understanding how bifacial solar panels perform compared to monofacial panels, how environmental factors affect the panels and how they perform with different surface coverings.

RES. Tom Duckett, EVP, RES in the Americas, says his company's engagement on the project provides a way to hone its expertise in the delivery of non-carbon-based energy. In a swift-moving industry, staying on top of current developments keeps the company in a leadership position, and stages it well to apply the lessons it learns here to other markets, for both domestic and global clients.

Duckett looks forward to seeing the data SwRI collects. "We see this as a partnership," he says. "We're a very engineering-focused company. Our engineering considers a tremendous number of variables, and we'll use the data to improve future solutions." Solar+Storage gives RES a unique opportunity to measure many of those variables over years to see how they change on a daily, weekly and annual basis. RES expects to validate and improve methods for sizing their solar and storage solutions. Moreover, they anticipate deepening their understanding of how a battery-solar combination can contribute to the grid, what factors affect optimization and how a municipal utility and research laboratory interpret the answers to these questions.

Since RES designs, engineers, constructs and operates photo-voltaic systems, one area of particular interest is research with new solar technology, including bifacial solar panels, which also receive sunlight reflected from the ground. In SwRI's smaller testbed, RES has placed frequent meters to monitor electricity generation on individual circuits. This will provide measurements for ground surfaces like gravel, grass or light landscaping fabric, and also allow side-by-side comparisons with single-faced panel photo-voltaics.

The Project: Today and Future

Easily visible just off San Antonio's Highway 151, Solar+Storage is built, operational and connected to the grid. First-year data will establish a baseline, influencing the project in coming years. After a year's worth of initial readings, where will the project go? For SwRI's Alger, that's still to be decided. "The one thing we can say for sure is that it'll generate power for CPS Energy. The other is that we'll learn as we go." With a 25-year expected life for the solar component and 20 years for the batteries, there is time for all parties to take initial readings, imagine new directions for research and test those directions on a working system. "At SwRI, we invent things, and invention doesn't have a time schedule. We'll see what we find out," adds Alger.

How to optimize battery use in the grid is a central topic of interest. Should batteries be completely charged, then completely discharged before charging again? Or are they more efficient when they remain, say, in the 20 to 80 percent charged range? How fast should they charge and discharge, and what results does that have? What effects does their application have on their useful life? Under what conditions should they receive electricity from the grid, and when should they reverse the flow in order to supply it? Are there other battery chemistries that might work better? "The best solution isn't just picking the best of everything," explains Alger. "We may have to de-optimize one part of the system to optimize the entire thing."

"This isn't just a science project," CPS Energy's Callender is quick to interject. "We are selling this every day on the market." The project is now a live part of the grid San Antonio customers depend on and benefit from. So the impact of Solar+Storage is not just in the future, but also the present. And the research isn't only technological, but also financial. Solar+Storage is as much

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— Wayne Callender, CPS Energy senior manager power plant

about exploring new business models as about exploring new technologies.

"This is not only a commercially viable project, it's also transformational [for CPS Energy]. It's the first solar farm we own outright and intend to operate ourselves. It's got to be repeatable, so we're taking the steps to make sure it can be," adds Boston.

While Solar+Storage adds to grid capacity and resilience, SwRI is collecting data on weather conditions, energy generation, battery degradation and a host of other factors. The first year's data will serve as an important baseline, allowing researchers to understand how the panels and batteries function together. After analyzing the first year's data, SwRI engineers will start to experiment in different ways.

SwRI is leaving the research direction open-ended for now, but expects the baseline data to indicate multiple promising directions. One interesting possibility: solar is typically 15-18 percent efficient when panels are clean, new and cool. Efficiencies degrade with time, though. "So, practically speaking, what is the best way to maintain them?" asks Sarlashkar. "Perhaps SwRI materials scientists will devise experimental coverings to repel water and dirt. Or is it more feasible to deploy workers or robots to clean panels and maintain the ground covering on a schedule?"

The lessons learned from Solar+Storage will achieve local, national and global reach. SwRI will promulgate its findings for the scientific community and industry by contributing to academic literature and participating in conferences. Visitors from the energy industry across the country and internationally have already begun to tour the site. But for CPS Energy, the education mission does not stop there. In the future, a visitor's center will introduce tours and school groups to the mission and technology of Solar+Storage, and monitors will display what the technology is doing in real time. At intervals, EPIcenter will publish status reports like this one as updates on the progress.

Above all else, though, is validating the basic Solar+Storage concept as a feasible solution to today's energy needs. "Part of success is showing that solar and storage can work together as reliable, clean, safe, secure power. If we can show this – can replicate a firm, reliable, dispatchable resource, and do it over a long period of time – that's a big win," says Eugster.

While she takes pride in the potential of Solar+Storage to help change the way the world generates and uses electricity, CPS Energy President and CEO Paula Gold-Williams remains focused on the impact it will make in San Antonio, Texas, her hometown. "We will expand our knowledge of solar energy and battery storage and further expand our energy expertise," she says. "We can do all of this while simultaneously meeting this community's demand for energy today and tomorrow."

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— Cris Eugster, CPS Energy Chief Operating Officer

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