RESILIENT POWER PROJECT CASE STUDY

MCKNIGHT LANE REDEVELOPMENT PROJECT

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RESILIENT POWER
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RESILIENT POWER PROJECT CASE STUDIES

This case study is one in a series by Clean Energy Group (www.cleanegroup.org) as part of The Resilient Power Project (www.resilient-power.org), a joint project with Meridian Institute (www.merid.org). This project seeks to expand the use of clean, distributed generation for affordable housing and critical community facilities to avoid power outages; to build more community-based clean energy systems; and to reduce the adverse energy-related impacts on vulnerable populations. The case studies produced seek to highlight installations of solar PV and battery storage (solar+storage) systems to demonstrate their economic, community resiliency, and health benefits. More information about this project and others can be found at www.resilient-power.org.

ACKNOWLEDGEMENTS

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VEIC, Efficiency Vermont, GMP, Sonnen, Vermod Homes, DOE-OE, and Sandia were central partners in developing the battery storage systems at the McKnight Lane project. Additional project partners included Vermont Housing Finance Agency, People's United Bank, Vermont Community Development Program, HOME Investment Partnership, Vermont Housing and Conservation Board, Efficiency Vermont, Clean Energy Development Fund, VLITE, National Association of Realtors®, Clean Energy States Alliance, the City of Vergennes, the Town of Waltham, Vermont Community Loan Fund, the Vermont Department of Environmental Conservation, and the Vermont Agency of Commerce and Community Development.

The views and opinions expressed in this report are solely those of the authors.

Cover image: Samantha Donalds/Clean Energy Group

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Waltham, Vermont

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Featured Installations Page: McKnight Lane Redevelopment Project

More information about this project can be found on the Clean Energy Group's website, under the Resilient Power Project's featured installation page. This webpage includes a project summary, photos, and links to additional project resources, including webinar recordings, blog posts, and news articles. This page is updated periodically with new information and materials.

www.cleanegroup.org/ceg-projects/resilient-power-project/featured-installations/mcknight-lane

Webinar: Year One Updates from the McKnight Lane Redevelopment Project

Clean Energy Group/ Clean Energy States Alliance hosted webinar, September 2017. Recording available at

www.cleanegroup.org/webinar/mcknight-lane-updates

Webinar: McKnight Lane: A Rural Low-Income Resilient Solar+Storage Housing Project

Clean Energy Group/ Clean Energy States Alliance hosted webinar, December 2016. Recording available at

www.cleanegroup.org/webinar/mcknight-lane

McKnight Lane Redevelopment Project

A defunct mobile home park in rural Vermont was transformed into the first resilient, zero-energy, affordable modular housing development in the country with solar and battery storage systems.

THE CHALLENGE: A Lack of Energy Resilience in Rural Affordable Housing

For people living in the rural town of Waltham, Vermont, affordable, energy-efficient housing is scarce. The one percent residential vacancy rate is less than half the national average, and over 40 percent of renters in the county are “rent overburdened,” meaning that they pay more than 30 percent of their income towards rent.[1] Most of the inexpensive housing stock in this rural area is comprised of older buildings and mobile homes, both notoriously expensive to heat. Vermont winters are long and cold, and heating fuels are expensive; this problem is made worse when heat is lost through single-pane windows and uninsulated walls. Electricity is also expensive, with Vermont’s average retail electricity rate ranking among the 10 most expensive states in the country.[2] This combination of inefficient housing, cold winters, and high energy costs creates a heavy economic burden for low-income families, who spend a disproportionate amount of their income on energy.[3]

In the event of a power outage, low-income households are again disproportionately impacted.[4] They may lack the resources to relocate even temporarily, which can pose a safety hazard if people are stuck in a home without heat, running water, or the ability to recharge cell phones. In addition, elderly and disabled individuals may rely on electricity for recharging electronic medical devices or keeping medications refrigerated. These hazards are exacerbated for people living in a rural area, where they may be isolated without access to neighbors or community centers. In rural wooded areas particularly, where miles of power lines are frequently at risk of interruption in times of high winds, ice storms, and heavy snows, power outages may be frequent.

Vermont experienced severe disaster-related grid outages first-hand in 2011, when Tropical Storm Irene’s heavy rains and fierce winds caused extensive damage and widespread power losses. The storm caused a significant amount of damage and destruction to low-quality housing, with a disproportionate amount of damage to mobile homes.[5] In the years following Irene, the state saw numerous efforts to increase community resilience, including projects that combined solar and battery storage both on the utility distribution grid and behind customer meters.

This shift toward resiliency has played out in many areas of the country, with advocates calling for the installation of solar PV plus battery storage (solar+storage) systems in affordable housing developments. Economic models show that in many cases, solar+storage systems placed at multifamily residential facilities can provide sufficiently large cost savings to pay for themselves within the lifespan of the technology.[6] This economic case rests primarily on the use of energy storage to achieve demand charge savings behind the customer meter (many multifamily residences are behind a single meter and are considered commercial customers, and therefore pay utility demand charges).[7] Where demand charges are high, the addition of energy storage can sometimes result in a shorter payback period than solar alone.

However, this economic case, which applies in many urban areas, is largely not transferable to rural areas, where affordable housing generally means temporary or poorly constructed individual homes rather than large multifamily facilities. These individual homes are typically considered residential, not commercial accounts, and therefore do not pay a separate utility demand charge. Furthermore, these homes rarely incorporate advanced electric heating systems, instead relying on interruptible deliveries of fuel oil or propane. Temporary housing is frequently constructed to low standards and not well maintained, meaning that roofs may not support solar PV; and because property values are low, financing for improvements is difficult to access. For all these reasons, owners of rural affordable housing face even higher barriers to the adoption of residential solar+storage than do owners of more urban affordable housing. However, the need for these systems in rural areas is the same, if not greater, than in urban areas.

The McKnight Lane Redevelopment Project demonstrates how the solar+storage solution can be applied to single-family affordable modular homes in a rural area. Rather than relying on behind-the-meter demand charge management to make the economic case, the project was installed as a "virtual power plant" with remote dispatch by the utility, Green Mountain Power (GMP), for use in reducing utility capacity and transmission costs.

THE SOLUTION: **Solar PV plus Battery Storage Systems**

The McKnight Lane Redevelopment Project transformed a defunct mobile home park in rural Vermont into the first resilient, net-zero, affordable modular housing development in the country. Solar+storage systems at each of the 14 single-family units provide low-income tenants with a continuous, uninterrupted power supply during grid outages, and the systems help these highly efficient homes achieve net-zero energy costs during normal operation. The all-electric, high-efficiency duplex modular homes demonstrate how energy efficiency, solar PV, and battery storage systems together can bring economic and energy security benefits to rural low-income families, while enabling the local utility, GMP, to manage costs related to peak energy demand, thereby reducing costs for all customers.

The McKnight Lane project was developed by the nonprofit affordable housing trust Addison County Community Trust (ACCT) and nonprofit affordable housing developer Cathedral Square. Pill-Maharam Architects designed the modular homes, and a local high-performance modular home builder, Vermod Homes, constructed them. Construction began in May 2016, and tenants moved into the units in October and November 2016 (see timeline, Appendix A).

Rents are below market, meaning the project serves households that earn no more than approximately $35,800, or 60 percent of the area's median income of approximately $59,700. Rent includes heat, air conditioning, hot water, and electricity, and laundry (washing machines and dryers are included in each home). All the units in the development project are powered, heated, and cooled entirely by electricity. The homes feature energy-efficient appliances and efficient heating, ventilation, and air conditioning (HVAC) systems. The homes exceed Efficiency Vermont's rigorous High-Performance Home standard. Two homes are fully accessible under the Americans with Disabilities Act (ADA) standards, and all homes incorporate Universal Design principles to be usable by people of diverse abilities.[8]

Project Overview

Owner: McKnight Lane is owned by a tax credit limited partnership with Addison County Community Trust (ACCT) as its General Partner. The property is managed by ACCT.

Location: Waltham, Vermont

Equipment: Thirteen of the 14 single-family units are equipped with a 6-kWh/ 4-kW AC smart solar energy storage system (the fourteenth unit has an 8-kWh/ 4-kW battery).

Installed cost: $3.6 million (includes site redevelopment, housing units, solar and storage)

Building loads supported: During a grid outage, the solar+storage systems will provide power to critical loads, including essential appliances, the ventilation system, and the heating and cooling systems.

Services provided: Backup power, cost savings through demand response, renewables integration.

Supported infrastructure: Affordable housing

Battery vendor: sonnen

Project partners: Vermont Housing Finance Agency, People's United Bank, Vermont Community Development Program, HOME Investment Partnership, Vermont Housing and Conservation Board, Efficiency Vermont, Clean Energy Development Fund, VLITE, National Association of Realtors®, Clean Energy Group, Clean Energy States Alliance, U.S. Department of Energy - Office of Electricity Delivery and Energy Reliability, Sandia National Laboratories, the City of Vergennes, the Town of Waltham, Vermont Community Loan Fund, the Vermont Department of Environmental Conservation, and the Vermont Agency of Commerce and Community Development.

Solar System Details

Solar System Size: Each of the 14 units has a 6-kW solar PV system

Configuration: Rooftop solar

Solar System 2017 Annual Production: 62,108 kWh

Solar System % of Load: 100%

Ownership Structure: Property owner owns the systems

Energy Storage System Details

Type of technology and size (power-kW / capacity-kWh): Thirteen of the 14 units have 6-kWh/4-kW AC lithium-ion smart solar energy storage systems; one unit has an 8-kWh /4-kW battery

Energy Storage Technology Provider: sonnen

Energy Storage System Location: Interior, in a mechanical room

Date of Service/Operation: October 2016

Energy Storage System Owner: Green Mountain Power, the local utility

Revenue Sources: The solar+storage systems were funded by Green Mountain Power, sonnen, Efficiency Vermont, High Meadows Fund, the Vermont Community Foundation Sustainable Future Fund through the Clean Energy Group, and the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability, and Sandia National Laboratories through the Energy Storage Technology Advancement Partnership (ESTAP), administered by the Clean Energy States Alliance.

Each home includes a sonnen ECO6 6-kWh or ECO8 8-kWh smart battery system. These systems automatically disconnect from the grid during a utility outage, powering the modular homes with stored electricity and recharging from the rooftop solar panels during daylight hours. During normal operations, the solar energy systems provide nearly 100 percent of the tenants' electricity needs. In the first full year of occupancy, project partners report that energy costs averaged $5 per month for each unit.

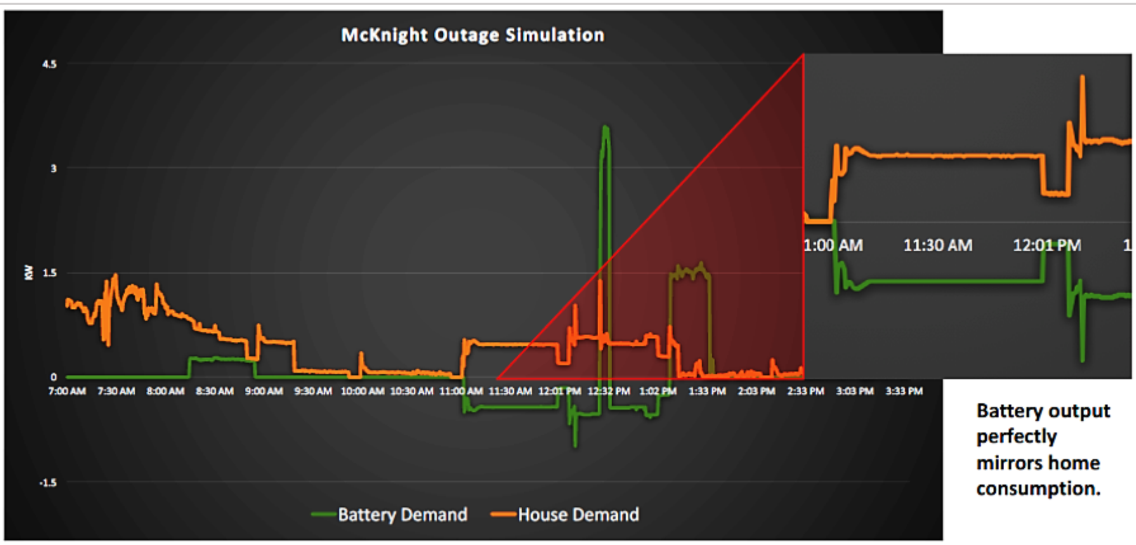
In most cases, the batteries are installed in the mechanical rooms of the modular homes (one home has the battery located in a hallway). They have displays showing their state of charge and how they are operating, but the battery containers are locked with no access to tenants. Green Mountain Power and the system manufacturer, sonnen, remotely monitor the systems and the ACCT property manager maintains them. ACCT property managers inspect the solar+storage systems regularly.

The batteries can provide backup power to critical loads for 3 to 5 hours at maximum consumption, depending on the size of the battery in each unit (most are 6-kWh batteries, but one is 8-kWh) and on the electric load during the outage. Green Mountain Power's average outage lasts two hours, so the batteries should support critical loads in the units through most outages. Critical loads that are supported by the batteries include cold climate heat pumps (for heating and cooling), energy recovery ventilation, refrigerators, all lighting, and some outlets.

Each home's solar PV system produces about 4-kW of power, which can be sent to the electrical grid, as needed, for net metering credit, or stored in each home's battery. Residents can monitor their generation and consumption in real time using online dashboards.

To date, the McKnight Lane property has not suffered a grid power outage. However, on March 24, 2017, GMP conducted a simulated grid outage event, and the batteries performed as expected, providing seamless backup power – see Figure 1, below.

Figure 1 – Results from Simulated Power Outage and Battery Performance



Event Schedule:

Time	Event	Duration
11:00 am	Grid Outage	2 hours
1:00 pm	Grid Connection	-

Results of a simulated power outage at a McKnight Lane Housing Development unit, conducted on March 23, 2017. The mean outdoor temperature was 19 degrees F, with a maximum of 32 degrees F. Source: Green Mountain Power.

FINANCIAL DETAILS

Project costs and grant funding. The total cost of the McKnight Lane Redevelopment Project, including site redevelopment, modular houses, solar and storage, was $3.6 million.

The energy storage systems cost $132,156, after a 25 percent discount from the supplier, sonnen. Funding for the energy storage systems was secured by Clean Energy Group/Clean Energy States Alliance, Efficiency Vermont, Green Mountain Power, sonnen, and other partners. Funding for the energy storage systems was provided by the following partners:

- Efficiency Vermont: $30,000
- Green Mountain Power: $45,000
- High Meadows Fund and the Vermont Community Foundation Sustainable Future Fund, through the Clean Energy Group: $27,156
- U.S. Department of Energy - Office of Electricity Delivery and Energy Reliability (DOE-OE) and Sandia National Laboratories, through the Energy Storage Technology Advancement Partnership (ESTAP), administered by Clean Energy States Alliance: $30,000

The economic case for energy storage. The solar+storage units at the McKnight Lane Redevelopment Project have resulted in financial benefits to both the tenants and owner, and to the electric utility serving the site. These savings are described in more detail below.

Low Electricity Costs for Owner and Tenants

The solar+storage systems keep electricity costs at the McKnight Lane units very low. Between January and August 2017, the average net cost of electricity per home (power, hot water, heating, and cooling) was $5 a month. Facility owner, ACCT, pays the utility bills for the site, so tenants are not directly paying electric bills (energy cost savings are passed along to tenants in the form of below-market rent). Affordable energy costs help ACCT provide affordable rental units for the low-income residents of Waltham.

Capacity and Transmission Savings for the Utility

The solar+storage systems also provide cost savings and other benefits to GMP, the utility that serves the project and a project partner. The batteries are used to help reduce the utility's costs for capacity, determined by the regional grid operator ISO-New England's Forward Capacity Market, and for transmission, determined by the ISO's Regional Network Services costs. GMP manages these costs by remotely discharging the battery during hour-long monthly and annual peak demand periods; by reducing its own demand during regional demand peaks, GMP reduces its overall cost for these services. To date, GMP has realized approximately $350 to $400 per month in savings from operating the McKnight Lane batteries for monthly transmission charge management. This transmission cost savings alone would achieve payback of 10 to 11 years for GMP's contribution to the cost of the battery purchase ($45,000); however, GMP should be able to additionally capture the annual capacity demand peak in most years, approximately doubling overall cost savings and halving the payback period.[9] In other words, GMP should be able to achieve payback for its investment in five years. Note that this does not mean the entire system cost will be paid back in that time.

In terms of per-kilowatt costs and savings, GMP contributed approximately $800/kW toward the purchase of the batteries. Assuming GMP can use the system to offset annual capacity and monthly transmission costs, and given the current value of these offsets, the utility should realize savings of approximately $1,500/kW (over an anticipated 10-year battery lifespan).

Energy Arbitrage Savings for the Utility

GMP is creating a platform that will give the utility the ability to use the McKnight Lane aggregated storage resource for energy arbitrage (that is, charging the batteries when market prices for electricity are low, and discharging them when prices are high). This will allow GMP to further lower its costs and pass additional savings to customers.

Other Benefits for the Utility

Other possible benefits to the utility include relieving grid congestion from solar generation, and delaying or alleviating the need for upgrading wires and transformers. In the northwestern section of Vermont, there is a high level of solar penetration. Energy storage can help soak up excess solar generation there during peak solar hours (at midday) by time-shifting solar exports to peak demand hours later in the day. This might allow GMP to defer or eliminate equipment upgrades, like installing new poles and wires or upgrading transformers and substations.

LESSONS LEARNED

Numerous lessons were learned throughout the development and initial operations of the McKnight Lane Redevelopment project.

Batteries Work, but Control Software Needs Improvement. The McKnight Lane project experienced both software and hardware problems that caused delays in successful implementation. There was one bad battery cell and one bad inverter, which were replaced. However, these hardware problems were limited. By comparison, the project has experienced ongoing problems with the battery manufacturer's control software, which allows GMP to remotely control the batteries. The proper functioning of this software is critical to the economical use of the batteries, because the utility needs to be able to reliably discharge the batteries as needed to reduce peak loads. Software issues led to a longer project implementation timeline than initially anticipated, and they have required frequent return visits to the site to correct new issues as they arose. Software problems also reduced the effectiveness with which GMP has been able to discharge the batteries, which in turn has reduced cost savings realized from the project.

Financing Challenges. To replicate this project, future solar+storage projects will need to be financeable. However, the 14 small batteries used in this project were too inexpensive to qualify for financing. In other words, banks and other lenders will not finance extremely small projects such as this one, because the amount of money involved is not worth their time (transaction costs are too high relative to returns on investment). If the batteries, solar systems, and other clean energy equipment had been wrapped into the overall mortgage that financed the 14 modular homes, the financing would not have been problematic. However, by the time batteries were added to the project, the modular units with the solar equipment had already been financed, leaving the batteries reliant on outside support from foundations and U.S. DOE-OE. Future projects should include specifications for energy storage equipment in the early planning stages to ensure that financing for these assets is part of the overall financial plan of the project.

A second financing issue encountered in this project was the inability of GMP, the owner of the batteries, to take advantage of the federal Investment Tax Credit (ITC) and accelerated depreciation when purchasing the batteries. The ITC and depreciation would ordinarily reduce the cost of the batteries by 50-60 percent. Although it had initially indicated that it would be able to take the tax incentives, GMP was ultimately unable to do so due to its tax status at the time of the purchase, and this increased the cost of the energy storage systems significantly. In future projects like this one, where the batteries are to be charged exclusively from solar and are thus eligible for the full ITC, it is important that the battery purchaser can take the tax benefits. If necessary, ownership of the energy storage systems could later be flipped to other project partners.

Ownership Model Replicability. The McKnight Lane project presented an unusual ownership model in which the local land trust owned both the underlying property and the modular homes. The land trust also paid all the utility bills for tenants. Because of this structure, the land trust could deal with the utility as a single, aggregated load. However, in many mobile home parks, tenants own their own homes and pay rent to occupy the land. In this more typical arrangement, individual tenants would likely be dependent on the landowner or an outside aggregator to negotiate a contract with the utility.

However, as utilities become more aware of the value of behind-the-meter resources, and they are able to aggregate and remotely dispatch those resources, this need for a third-party aggregator may diminish. We are beginning to see evidence of such a change in awareness among utilities. For example, GMP now offers a residential Tesla battery program in which customers pay $15 per month for a battery, which provides them with resiliency benefits. Under this program, the utility acts as an aggregator and uses the customer-sited batteries to reduce capacity and transmission costs (the same economic model used at McKnight Lane). GMP has also put forth an alternate model in which the customer may own the battery, and the utility purchases rights to use it. Similar residential battery programs have been piloted by several utilities in other states, including Southern California Edison in its Preferred Resources Pilot,[10] and Sunverge in Arizona.[11] A similar pilot has been proposed by Liberty Utilities in New Hampshire.[12]

Perceived Risks of New Technologies. Most housing developers and landlords are not well versed in emerging solar+storage technologies, financing, economic models, safety, operations and maintenance, markets, and other areas critical to the successful development and operation of a battery storage project. They are understandably hesitant to invest in a technology they do not understand. This hesitation is exacerbated by the widespread perception that energy storage manufacturers and vendors are largely start-up companies without a strong history of commercial success.

Anticipating the need to reduce risk and the perception of risk in the McKnight Lane project, project partners had to learn to install, maintain, and operate the batteries. Local first responders needed training on safety matters, and Efficiency Vermont conducted maintenance and software updates on site. CEG/CESA worked to raise grants funds with the Vermont Energy Investment Corporation and developed educational materials to inform tenants about the batteries located in their homes.

To reduce these perceived risks, battery storage companies and associated service industries need to offer insurance and warranties, operations and maintenance services, financing, leasing or third-party ownership models, decommissioning services, recycling and replacement services, aggregation services, and other services that property owners and managers expect when evaluating a technology.

Battery Footprint Issues. The sonnen batteries used at McKnight Lane were chosen, in part, due to space constraints. In fact, the design and construction teams abandoned an earlier plan to use Tesla Powerwalls in this project because there was not enough space in the modular homes' mechanical rooms to accommodate them. The sonnen battery was able to fit within the available space in the mechanical rooms. If batteries are to be offered to low-income residential customers in any meaningful way, manufacturers will need to offer more compact designs that can fit within limited space. Because low-income tenants in many parts of the country do not typically have a garage, the wall-mount design may not be a good one for this market.

As with the financing challenges, footprint issues might have been more effectively addressed had consideration of the energy storage component been part of the early design work, rather than a late addition to the project. However, it is likely that retrofit projects such as this one in residential installations will remain common for the foreseeable future. The implication of this is that battery manufacturers will need to produce modular, flexible designs that can accommodate a variety of siting and operational needs.

Customer Interface Issues. The sonnen batteries used in the McKnight Lane project display operational data in real time on a display panel mounted to the outside of the battery container. Unfortunately, these displays also come equipped with a power cycling button, which presented the danger that residents could inadvertently turn off the batteries. In order to avoid this risk, changes to the onboard controls were required when the batteries were installed. This problem is not specific to low-income settings, but would be a concern in any residential energy storage project where children could have access to the battery. Redesigning the product so that controls are located inside the locked container would address these issues.

APPENDICES

A. Project Timeline
B. Battery System Performance Data
C. Photos

APPENDIX A: Project Timeline

May 2016
Demolition begins on 13 vacant mobile homes at the former Gevry mobile home park in Waltham, Vermont. Addison Country Community Trust begins accepting rental applications for new duplex, single-family housing.

July 2016
First two Vermod units are delivered and installed.

September 2016
ACCT and Efficiency Vermont host open houses for prospective tenants.

October 2016
Housing development opens.

November 2016
Construction and development is completed, and all units are occupied.

APPENDIX B: Battery Performance Data

Figure 2 shows the sonnen battery dashboard displaying the activity of a single battery in the McKnight project during several days in February 2018. The dashboard shows battery charge and discharge, state of charge, PV production and electricity consumption for each unit. The red bar indicates a period during which GMP remotely discharged the battery to attempt to offset transmission costs during a monthly transmission peak period. Each of the 14 batteries in the project can be remotely monitored. This chart was generated using sonnen's online interface for system managers.

Figure 2 – Battery Performance and Usage Display

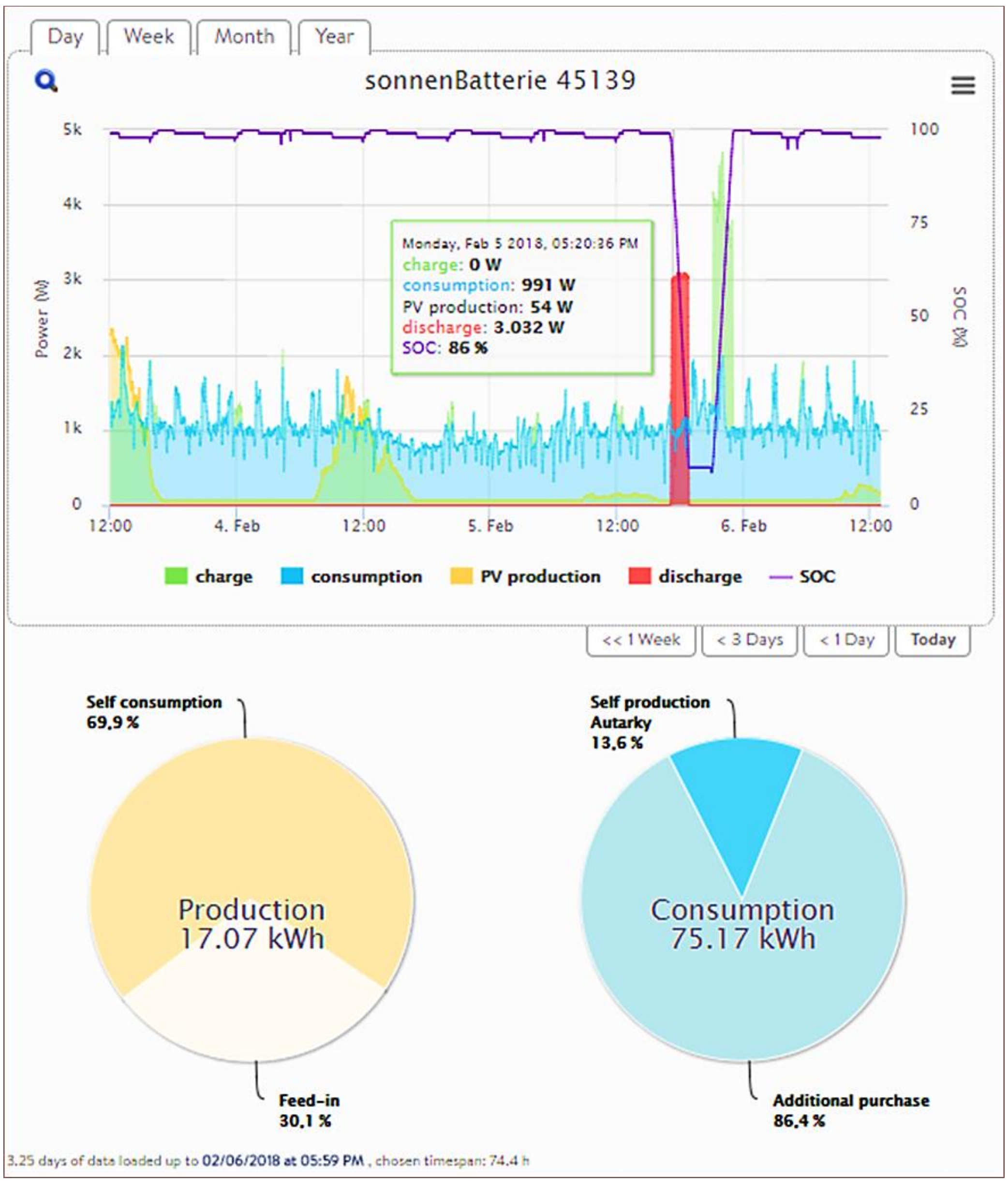
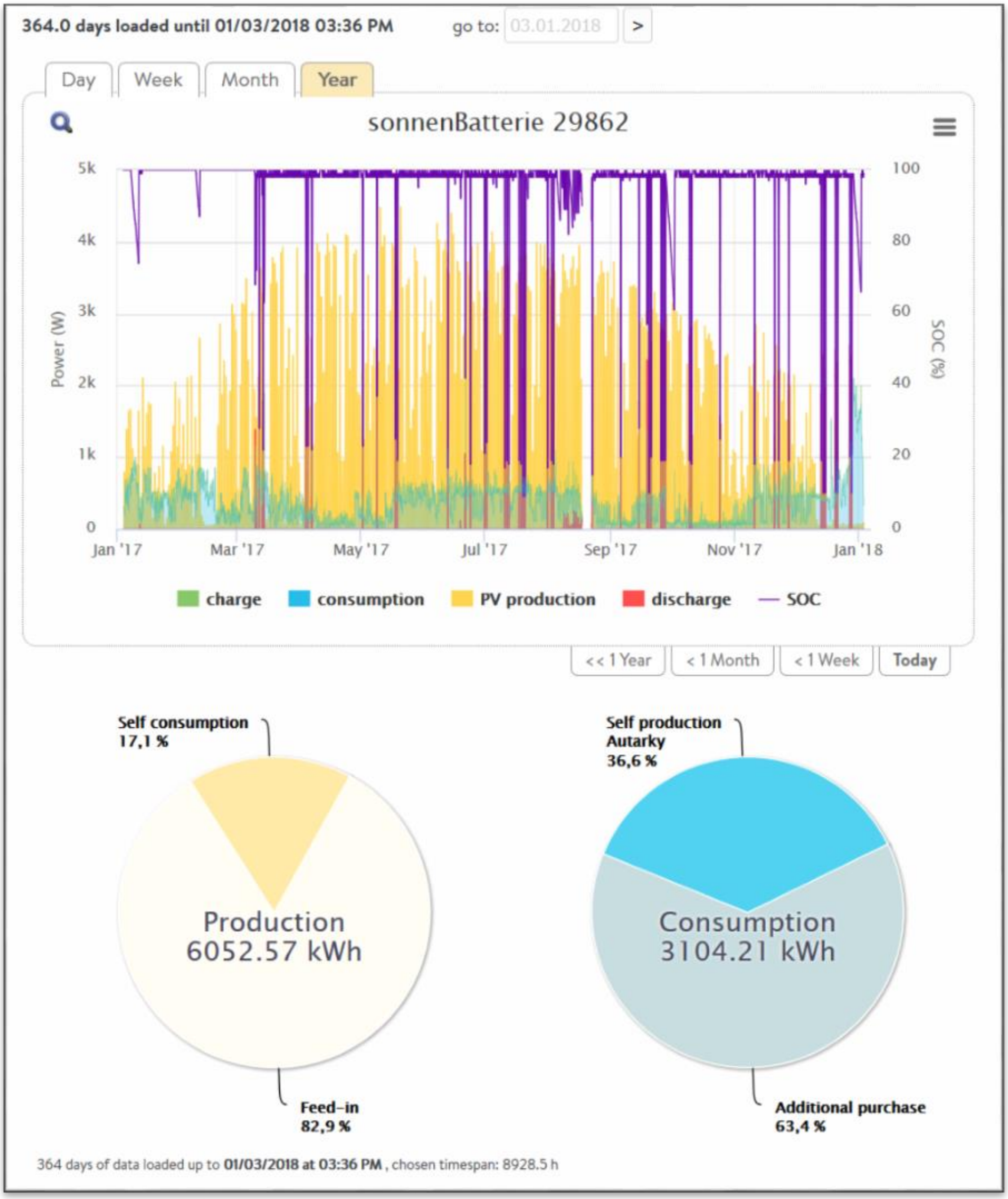


Figure 3 shows the performance data for one of McKnight Lane's battery storage units over a year, from January 2017 to January 2018. This chart was generated using sonnen's online interface for system managers.

Figure 3 – Battery Performance Data over One Year



APPENDIX D: Photos

These and additional photos of the McKnight Lane Redevelopment Project are available at https://www.flickr.com/photos/cleanenergygroup/albums/72157683433173954

Endnotes

[1] See: "FY16 Community Needs Assessment," Champlain Valley Office of Economic Opportunity, 2016 https://www.cvoeo.org/fileLibrary/file_259.pdf. See also: "2015-2020 Addison County Housing Needs Assessment," Bowen National Research, 2015 http://accd.vermont.gov/housing/plans-data-rules/needs-assessment.

[2] U.S. Energy Information Administration, 2016 https://eia.gov/electricity/state/

[3] See the 2016 report by Energy Efficiency for All and the American Council for an Energy-Efficient Economy: "Lifting the High Energy Burdens in America's Largest Cities: How Energy Efficiency Can Improve Low-Income and Underserved Communities," available at: http://energyefficiencyforall.org/sites/default/files/Lifting%20the%20High%20Energy%20Burden_0.pdf. See also this 2016 report by Groundswell. "From Power to Empowerment: Plugging Low Income Communities into the Clean Energy Economy," available at https://groundswell.org/frompower_to_empowerment_wp.pdf. See also a map from Inside Energy on how much America's poorest households spend on energy, available at http://insideenergy.org/2016/05/08/high-utility-costs-force-hard-decisions-for-the-poor/ and https://jordanwb.carto.com/viz/b9087820-13af-11e6-ba75-0ecd1babdde5/public_map.

[4] See: "A Disaster in the Making: Addressing the Vulnerability of Low-Income Communities to Extreme Weather," Center for American Progress, 2013 https://americanprogress.org/wp-content/uploads/2013/08/LowIncomeResilience-2.pdf.

[5] See: "Report on the Viability and Disaster Resilience of Mobile Home Ownership and Parks," Vermont Department of Housing and Community Development, 2013 www.leg.state.vt.us/reports/2013externalreports/295178.pdf.

[6] For more on this topic, see Clean Energy Group's 2017 report, "Solar Risk: How Energy Storage Can Preserve Solar Savings in California Affordable Housing," available at www.cleanegroup.org/ceg-resources/resource/california-solar-risk

[7] Clean Energy Group produced a 2-page introductory fact sheet on demand charges, available at www.cleanegroup.org/ceg-resources/resource/demand-charge-fact-sheet

[8] Read more about the McKnight Lane units at www.addisontrust.org/mcknight-lane.html.

[9] GMP failed to capture the annual capacity peak in 2016, which came quite early in June (capacity peaks in New England have historically occurred in July or August).

[10] "SoCal Edison's Grid Edge Experiment Contracts for 125MW of Batteries and Demand Response," by Jeff St. John, *Greentech Media*, 9/13/2016 https://www.greentechmedia.com/articles/read/socal-edisons-grid-edge-experiment-contracts-for-125mw-of-batteries-and-dem#gs.8lXBghA

[11] "Arizona Public Service taps Sunverge for residential energy storage pilot," by Robert Walton, *Utility Dive*, 11/28/2017 https://www.utilitydive.com/news/arizona-public-service-taps-sunverge-for-residential-energy-storage-pilot/511748/

[12] See NH PUC's docket on the storage pilot at www.puc.state.nh.us/Regulatory/Docketbk/2017/17-189.html

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