Stafford Hill Solar Farm and Microgrid

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January 2019

RESILIENT POWER
A Project of Clean Energy Group and Meridian Institute

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. This case study series highlights 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.

ACKNOWLEDGEMENT

The author would like to thank Josh Castonguay of Green Mountain Power (GMP) and Susan Schoenung of Longitude 122 West, Inc. for their review and valuable input on this report. He would also like to thank Dr. Imre Gyuk at U.S. Department of Energy - Office of Electricity, and Dan Borneo and Ben Schenkman at Sandia National Laboratories, whose funding and support made the project possible. Jane's Trust also provided support for the development of educational materials regarding this project and this case study.

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Cover image: Stafford Hill Solar Microgrid. Credit: Green Mountain Power.

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www.cleanegroup.org/ceg-projects/resilient-power-project/featured-installations/stafford-hill

Webinar: A Solar Storage Microgrid for the Energy City of the Future

Clean Energy States Alliance hosted webinar, August 2014. Recording available at:

www.cesa.org/webinars/estap-webinar-a-solar-storage-microgrid-for-the-energy-city-of-the-future

Green Mountain Power (GMP): Significant Revenues from Energy Storage

Sandia National Labs, May 2017

This report provides an analysis of the economics of the Stafford Hill microgrid project

www.cesa.org/resource-library/resource/green-mountain-power-gmp-significant-revenues-from-energy-storage

RE-Powering America's Land: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites – Traditional New England City Builds a Modern Microgrid

U.S. Environmental Protection Agency, July 2016

This case study describes the Stafford Hill microgrid project.

https://www.epa.gov/sites/production/files/2016-07/documents/re_on_cl_rutland_case_study.pdf

Stafford Hill Solar Farm and Microgrid

Vermont's largest utility installed a solar+storage microgrid in Rutland, VT that saves hundreds of thousands of dollars and can supply backup power to an emergency shelter.

THE CHALLENGE: **Increasing Costs and the Need for Resiliency**

Tropical Storm Irene hit Vermont in August 2011, dumping 11 inches of rain on parts of the state, where rivers were already high from a wet summer and heavy snowfalls the previous winter. The storm delivered the worst flooding the state had seen in 84 years. It left entire towns isolated by washing away roads and bridges, and devastated homes and disrupted the state's emergency operations center. The massive flooding led to six deaths, and the storm left 117,000 people (about one sixth of the state's population) without power and resulted in hundreds of millions of dollars in damage.[1]

At the same time, capacity and transmission costs were rising – and were expected to remain high – for utilities in the ISO-New England (ISO-NE) region, including Vermont's largest utility, Green Mountain Power (GMP). The utility is based in Rutland, Vermont, a city that was hit particularly hard by Irene.

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

Solar and energy storage presented not only an opportunity to cut operating costs for GMP, but also a means to provide backup power to critical emergency services, should a disaster of Irene's magnitude occur again.

The Stafford Hill Solar Farm in Rutland, Vermont was built in 2015. The project, developed by GMP, includes 7,700 solar panels capable of producing 2.5 megawatts (MW) of electricity, which is enough to power about 2,000 homes. It also includes 4 MW / 3.4 megawatt-hours (MWh) of lead-acid and lithium-ion battery storage.

The project was supported through a grant from Vermont Department of Public Service and another grant from U.S. Department of Energy, Office of Electricity. It received technical support from Sandia National Laboratories and the Clean Energy States Alliance.

The project was developed as a microgrid that provides resilient backup power to a nearby Red Cross emergency shelter at Rutland High School, supplying clean, distributed generation and resilient power to an economically challenged, urban community. Rutland also suffers frequent power outages due to severe winter storms. The project also makes meaningful progress toward managing the integration of large amounts of solar PV that GMP has developed in Rutland, and it provides additional cost-saving grid services, demonstrating the cost-effective operation of energy storage.

Project Overview

Project Developer/Owner: Green Mountain Power

Location: Rutland, Vermont

Equipment: 2.5 MW solar PV and 4 MW / 3.4 MWh lithium-ion and lead acid batteries; custom multiport inverter

Installed Cost: $5,500,000 (battery costs exclusive of solar costs)

Payback Period: 8 years

Supported Infrastructure: Red Cross emergency shelter at a regional high school

Building Loads Supported: Heating, lights, building infrastructure

Services Provided: Annual and monthly peak demand management, energy arbitrage, frequency regulation, backup power

Project Partners: Green Mountain Power, Vermont Department of Public Service, U.S. Department of Energy, Sandia National Laboratories, Clean Energy States Alliance

Project Funding: $250,000 from U.S. Department of Energy; $40,000 from Clean Energy Development Fund at the VT Department of Public Service; in-kind technical assistance from Sandia National Laboratories and the Clean Energy States Alliance.

Solar System Details

Solar System Size: 2.5 MW

Configuration: Ground-mounted solar farm

Provider: Solar PV panels by groSolar, inverters by Dynapower

Ownership Structure: Owned by Green Mountain Power

Revenue Sources: Electricity generation, RECs

Energy Storage System Details

Type of Technology and Size (power / capacity): 500 kW/600 kWh lead acid & 500 kW/250 kWh lithium-ion batteries

Provider: Dynapower

System Location (interior/exterior): Outdoor containers

Date of Service/Operation: 2015

Ownership Structure: Owned by Green Mountain Power

Installed Cost: $5,500,000

Revenues Sources: Annual peak capacity reduction, monthly transmission peak reduction, energy arbitrage, frequency regulation

The Stafford Hill microgrid represents several firsts. The project was the first solar-powered microgrid to provide backup power to a public emergency shelter, as well as the first microgrid developed on a brownfield site, what was formerly the Rutland City landfill. Importantly, it was the first large-scale project in the New England region to demonstrate how utilities in ISO-NE can use batteries to significantly cut their costs and has inspired the development other projects in the region. GMP itself followed the project with a second large-scale battery installation in Panton, VT, and has additionally launched to residential customer storage programs, installing more than 1,000 small batteries behind customer meters. The Stafford Hill project is called out for replication in Vermont's Comprehensive Energy Plan. Many Vermont-based companies were used for equipment and installation, including solar panels provided by groSolar and batteries and inverters from Dynapower.

Several key technical features of this solar+storage system are described below.

Backup Power. A central component of the microgrid's design is to supply backup power to a public emergency shelter at Rutland High School. The typical critical load at the school, including heating, lights, and building infrastructure, is estimated to be 100 kW, but it can be as high as 250 kW in the winter. To supply backup power, the microgrid is capable of disconnecting from the larger electricity grid during power outages. It can operate independently of the utility electric grid using the installed PV and batteries and can supply power from the solar panels and battery to the emergency shelter until grid power is restored. Due to the size of the solar+storage resource, which is much larger than the critical load at the shelter, the project should be able to support the shelter load indefinitely in all seasons except winter, and for at least several days in the winter.

Year-Round Cost Savings. When connected to the grid, the microgrid generates and stores power for GMP, furthering renewable energy integration and providing cost savings through annual and monthly peak demand management, energy arbitrage, frequency regulation.

FINANCIAL DETAILS

The Stafford Hill battery system had an installed cost of $5.5 million after the project cost was reduced by grant funds from two sources, including $250,000 from the U.S. Department of Energy and $40,000 from the Vermont Department of Public Service. Additionally, technical support was provided by Sandia National Laboratories and the Clean Energy States Alliance.

One objective of the project was to assess the financial value of energy storage operating within the overall GMP system. According to a 2016 case study by the U.S. Environmental Protection Agency,[2] Green Mountain Power expected the near-term cost savings of the energy storage portion of the project to amount to $350,000 to $700,000 per year. The project also benefits the city of Rutland, by providing lease payments of $30,600 each year for use of the closed landfill site plus reliable backup power for its emergency shelter.

Tax Credits. According to a case study by the U.S. Environmental Protection Agency,[3] the project developer, Green Mountain Power, was able to take advantage of federal incentives for the system through investment tax credits and modified accelerated depreciation.

Regional Network Service Savings. The battery can reduce the monthly transmission charge that GMP pays for Regional Network Service (RNS) savings, which is calculated based on GMP's demand during the statewide peak transmission hour each month. By timing dispatch of the battery to reduce demand during that monthly peak hour, the Sandia report[4] estimated that GMP could save $7,850 per reduction of 1,000 kW in 2017, a reasonable estimate for this project. These savings accrue each month that the peak is effectively reduced, meaning the total RNS savings for the year could be $94,230. Savings could increase to $103,000 per year as RNS costs rise in the future.

Forward Capacity Market Savings. The largest energy cost savings potential from the batteries comes from the reduction of GMP's electricity demand during a single, annual peak-demand hour for the ISO New England region. On August 12, 2016, in its first year of operation, the project shaved enough peak demand to save its customers over $200,000 during a single hour.[5] At a time when summer temperatures were in the nineties, GMP used its batteries to reduce its contribution to the New England grid's peak hour of demand, when the cost of power was most expensive. Instead of meeting customer needs with electricity managed by the grid operator, ISO-NE, GMP used local electricity generated by the solar farm and stored in the batteries. The batteries were used for peak shaving at a value of about $102,000 during that peak hour and the solar PV saved another $100,000 through load reduction during that same time.

These savings are based not on the volumetric cost of electricity, but on the reduction of capacity charges. By lowering its load during the regional annual load peak, GMP and other utilities can lower the overall amount they are charged for capacity services over the year. The amount of the reduction depends in part on the price of capacity, which is determined in a three-year forward auction.

By installing additional batteries since the successful deployment of the Stafford Hill project, GMP has increased its annual savings due to capacity and transmission cost reductions. In 2018, GMP was able to dispatch not only the Stafford Hill system, but also a second large battery system at Panton, VT and more than 1,000 Tesla PowerWalls installed behind customer meters, for a combined peak reduction of more than 6 MW during the August 29th peak, which was worth more than $755,000. GMP's savings calculation for this one-hour battery use is shown in **Table 1**.

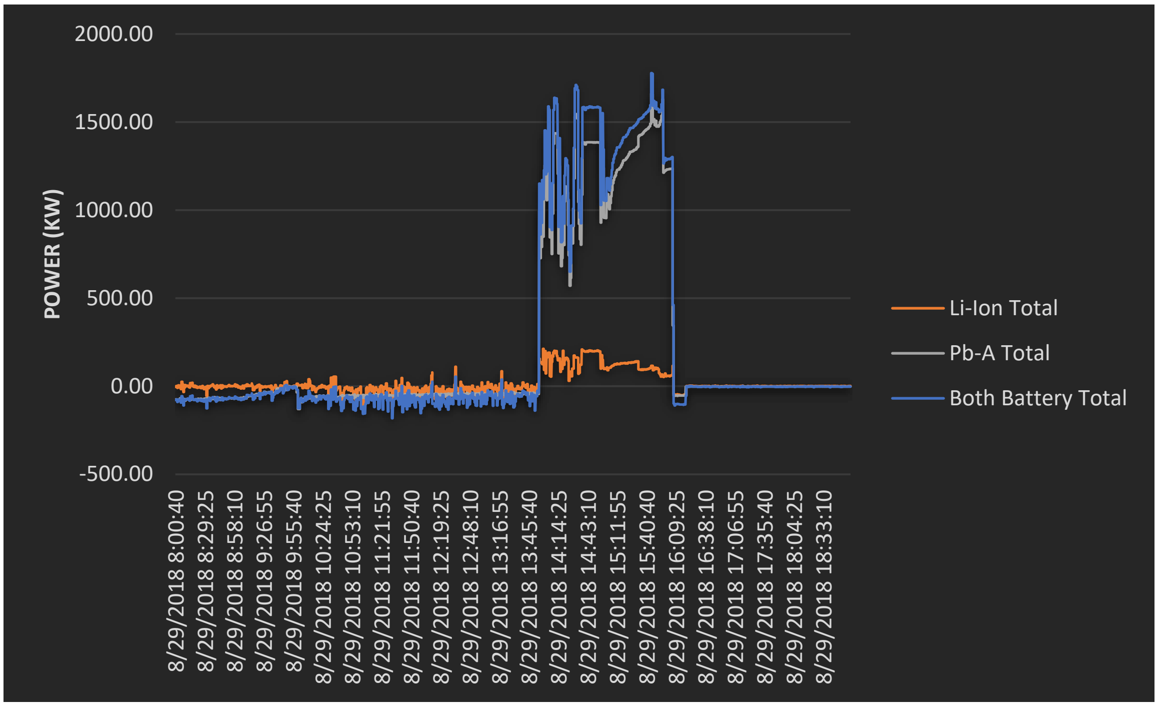
Table 1: Calculating August 29, 2018 Regional Peak Savings for GMP

Item	Value / Units	Explanation
Current FCA Price	7.03 $/kW-month	Forward Capacity Market Clearing Price
Installed Capacity Requirement factor	1.35	Reserve margin requirement
Peak Loss Reduction factor	1.08	Distribution system loss percentage
Peak Reduction during event	6.14 MW	Combined Panton, Stafford Hill and Power Wall ES operations
Total reduction (savings x reserve margin x loss reduction factor)	8.95 MW	= 6.14 MW x 1.35 x 1.08
Total peak reduction value	**$755,201**	=8.95 MW x 7.03$/kW-month x 12 months

Source: Green Mountain Power

The operation of the batteries at GMP's Stafford Hill facility during this annual peak is shown in **Figure 1**. The variations in output occur because the solar PV shares the multiport inverter with the batteries, and the total output is limited to 2 MW, meaning the batteries reduce their output when the solar is generating (solar output is not shown in this graphic).

Figure 1: Battery Operation at Stafford Hill on August 29, 2018



Source: Green Mountain Power

Ancillary Grid Services. Ancillary services encompass a suite of products that support power system reliability. One such service, called frequency regulation, is the balancing of electricity supply and demand to keep frequency within operational bounds. It includes services for responding to both increases and decreases in system frequency (often called regulation-up and -down, respectively). The batteries installed at Stafford Hill are capable of being used for frequency regulation (both regulation-down and -up) and would require GMP to bid into the ISO-NE system using certain tariffs and with facilitation from a third-party scheduler. Estimated values for frequency regulation in the ISO-NE region are up to $150/kWh/year, according to a recent report by Sandia National Laboratories, titled "Green Mountain Power (GMP): Significant Revenues from Energy Storage."[6] Another recent Sandia report, titled "The Value Proposition for Energy Storage at the Sterling Municipal Light Department," summarizes a municipal utility-owned energy storage project in Sterling, Massachusetts, and there this service was valued at $60,476 per year for a 1 MW / 1 MWh battery.[7]

Demand Response. Demand response provides another dimension of control to power system operators, and helps operators avoid power interruptions at times when consumer electricity demand threatens to exceed available generation supply. A demand response product is available in the ISO-NE region, but is not currently being used by the Stafford Hill project, as GMP is currently focusing its attention on refining participation in frequency regulation. Note that the ability of energy storage to participate in regional energy markets like the frequency regulation market is subject to regulatory changes, such as are underway in ISO-NE and other ISOs and RTOs due to FERC Order 841.

Energy Arbitrage. Energy arbitrage, or storing energy produced during periods when wholesale electricity prices are low to be sold into the power system later when market prices are higher, was found to be potentially profitable, with gross revenue potential as high as $13/kWh/year or $70,000 in total per year. However, GMP is not currently using its batteries for this application.

Renewables Integration. As is described in the recent report by Sandia National Laboratories,[8] Vermont has seen a significant increase in installation of solar power, and transmission has become congested in some areas. Additional increases in solar generation may create integration and grid stability problems in areas of higher solar penetration. The GMP microgrid project was originally conceived in part as a solution to problems caused by an unusually high level of solar penetration in the Rutland area. In fact, GMP's plan for the revitalization of Rutland included installing enough solar PV to make the city the "solar capital of New England," which it accomplished in 2015.[9] With more solar per capita than any other city in the region, Rutland was facing distribution infrastructure challenges that were addressed by the addition of the Stafford Hill batteries, which help to reduce line congestion.

Educational Value. The Stafford Hill project includes two displays, one each at Rutland High School and the Energy Innovation Center in downtown Rutland, that show real-time data of energy being produced, stored, and dispatched. The display also shows information on the environmental and societal impacts of the project including future uses, such as charging electric vehicles and additional benefits to the grid, and the functions, benefits, and challenges of developing a microgrid. Displays about microgrids, renewables, and grid storage technologies and economics are included as well. Surrounding schools are invited to visit the both sites to see this information in real time.

Payback Period. After accounting for grant contributions, the project cash flow is expected to turn positive in year eight, according to cash flow analysis in a recent report from Sandia National Laboratories (it would be nine years without the grant funds).[10] Cash flow is based on projected values, so the actual period may change based on real-world cost savings.

LESSONS LEARNED

A list of lessons learned from this project is included in the Sandia report.[11] For example, GMP has learned that while the use of multi-port inverters can reduce project cost, they can also cause constraints on output from both the solar PV and batteries, which can limit opportunities for cost savings and revenue earnings. Several other lessons learned are described below.

Engineering, Procurement, and Construction Package. According to a recent case study on the project produced by the U.S. Environmental Protection Agency,[12] Green Mountain Power served as its own general contractor to develop the Stafford Hill Microgrid. "GMP staff designed the system, procured the solar, coordinated with Dynapower on the battery system design and purchase, garnered permits, and more." In the future, GMP plans to use an Engineering, Procurement, Construction (EPC) package, reducing GMP's time and direct involvement in developing the project, with the utility's role primarily being focusing on the operational and grid aspects of the project.

Extending Battery Life. There are several factors that are important for maximizing battery life, and these are discussed in more detail in the Sandia report.[13] They include ambient temperature, state of charge, and cycle count. The lithium-ion and lead acid batteries have different optimal operating parameters, as demonstrated by this project. In addition, battery life can be affected by which applications the batteries are used for. In order to extend battery life and maximize opportunities for cost savings over the life of the project, utilities like GMP have opted to forego some battery applications that require frequent cycling and have relatively low value, such as frequency regulation, in favor of higher-value, less frequent applications, such as demand management. This is a calculation that would need to be made separately for each project, as it depends on the values of various applications and the type of technologies involved.

Battery Technology. This project included both lithium-ion and lead acid batteries, which were to be used in different ways given known best practices for each technology. Typically, lithium-ion batteries have been used for shorter-term cycling, in applications such as frequency regulation and renewable generation smoothing, while lead acid batteries lend themselves to longer cycles. In subsequent battery projects, GMP has chosen to use lithium-ion batteries exclusively, likely reflecting their decreased costs and increased versatility for a variety of applications.

Data Access. One of the goals of the GMP project was to provide operational data for analysis (and the project received federal and state grants in part to ensure that data would be publicly available). Sandia National Laboratories, which provided technical support to the project, was to collect this data remotely from the project site. To enable this, the project was supposed to include 30 days of on-site data storage, and real-time remote access by Sandia. However, neither of these requirements was initially met, and this led to three years of remedial work. Although the project was completed in 2015, reliable remote data access was not achieved until late in 2018, resulting in three years of lost data and significantly higher expenses to remediate the problem.

Timely Dispatch. GMP's primary cost-saving applications for the battery project require accurate and timely dispatch to offset the utility's load during regional demand peak events. GMP has improved in accurately predicting these peaks, however, the utility did miss the 2017 annual peak, which occurred in June (earlier than usual, as most peaks have historically occurred in July or August). Since the annual peak can be worth hundreds of thousands of dollars in cost savings, hitting it consistently is important. Some other utilities have turned to third parties to dispatch their battery systems and have reported an increase in accuracy.

PROJECT RECOGNITION

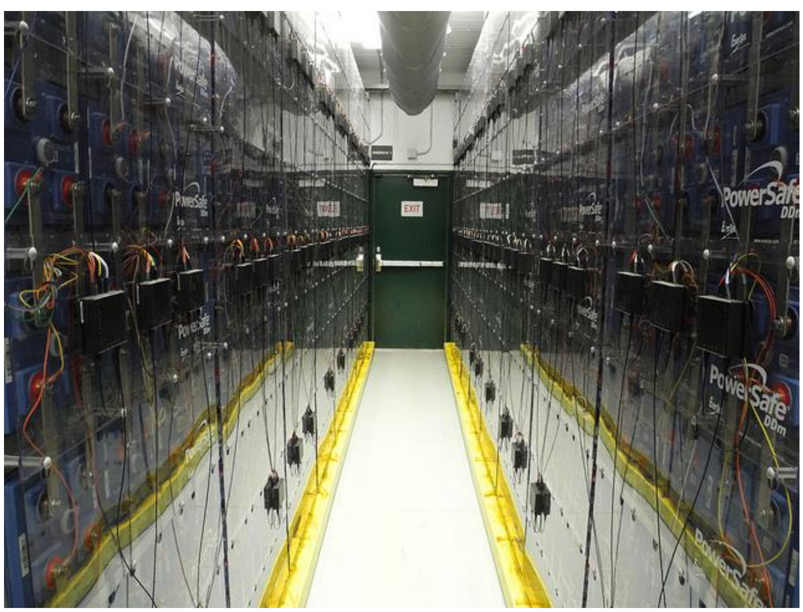
The Stafford Hill Microgrid was a recipient of the 2015 PV Project of Distinction Award presented by the Solar Electric Industries Association and the Solar Electric Power Association.[14]

The project is highlighted in the Vermont Comprehensive Energy Plan as a model that should be replicated.[15]

PHOTOS

These and additional photos of the Stafford Hill Microgrid groundbreaking event in August 2014 are available at https://flic.kr/s/aHsm1KmErA.

View of the battery storage unit at the Stafford Hill Microgrid site in Rutland, Vermont.
Credit: Maria Blais Costello, Clean Energy Group.



View inside the battery storage unit at the Stafford Hill Microgrid site in Rutland, Vermont.
Credit: Maria Blais Costello, Clean Energy Group.

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