5.2 Case Study 2: Stafford Hill Solar Farm

The Stafford Hill Solar Farm is a solar + storage microgrid project under development by Green Mountain Power (GMP) in Rutland, Vermont, partially funded by a Federal/state/nongovernmental (NGO) partnership involving the State of Vermont, U.S. DOE's Office of Electricity, and the Energy Storage Technology Advancement Partnership (ESTAP). ESTAP is managed by the Clean Energy States Alliance (CESA) and Sandia National Laboratories.

According to the DOE, the Stafford Hill Solar Farm is the first project to establish a microgrid powered solely by solar and battery backup, the first to provide full backup to an emergency shelter on the distribution network, and the first to site solar arrays on brownfield land once used to bury waste. The solar array is pictured in Figure 7, below. The $10 million project is expected to be completed in 2015.

Figure 7. Stafford Hill Solar Farm

Source: Green Mountain Power[9]

5.2.1 Background and Project Objectives

In 2012, GMP merged with another utility (CVPS), which was headquartered in Rutland. As part of an effort to demonstrate continued commitment to the City of Rutland, the new company deemed Rutland the solar capital of New England and set the goal of installing the most solar per capita in New England. Shortly after this, GMP leased an old landfill (capped by the City of Rutland 30 years ago) that would become the site of the Stafford Hill Solar Farm. As there was no more landfill gas to be extracted from the site, the city agreed to lease the land to GMP. GMP designed the 2.5 MW solar project to occupy 11 acres of the landfill.

The development and permitting process began as a standard utility-scale solar PV plant. However, midway through the project design phase, GMP began to explore the prospect of installing energy

[9] "The Stafford Hill Solar Farm." Web. Green Mountain Power, 2015. Available at: www.greenmountainpower.com/innovative/solar_capital/stafford-hill-solar-farm/

storage in partnership with DOE and the State of Vermont. After exploring the opportunity, GMP decided to restart the permitting process as a solar + storage microgrid package.

In addition to developing the partnership with DOE, GMP was able to orchestrate many stakeholders to develop the project. Dynapower, a local company based in South Burlington, Vermont, assisted with the proposal for the DOE grant, and provided engineering and procurement services for the power systems technology. Dynapower also coordinated a bid to procure the most cost-effective battery storage technology. GroSolar was the winning bidder on the solar installation, and it is responsible for integrating the solar into the power electronics and the inverter. Vermont Energy Investment Corporation (VEIC) is working to develop educational tools for the project, and will be installing digital kiosks in the school to demonstrate real-time performance of the solar and storage. Finally, the City of Rutland was glad to lease the site and the landfill to GMP to fulfill its renewable energy goals.

The project site and design offered myriad benefits, including the opportunity for brownfield redevelopment, backup power and islanding capabilities for an emergency shelter in the neighboring high school, the ability to provide ancillary services to the New England-Independent System Operator (NE-ISO), and peak shaving of GMP's load with timed battery discharge. Additionally, the site in Rutland provides positive publicity for both the community and the utility and fulfills renewable energy goals for the city. As one project representative stated:

"The selling point—the pitch—we wanted to really test was to see how many different value streams we could really extract from this project. We have already tested and we have done a lot of solar. Energy storage is brand new to us."

Since the project was new to both the utility and the regulator, the process for permitting the development was educational for both parties. GMP finally received the green light from the regulator to develop the project in July 2014, and the project is now in the final stages of construction. Locating the project on a landfill added a new level of complexity to the development. For example, the drawings for the old landfill were inaccurate. They discovered trash where they needed to sink foundations into solid ground, which forced a project delay and redesign. The solar installation was complete as of March 2015, the containers with the battery storage are installed, and GMP is targeting activation in early June 2015. As construction finishes, the foremost concern is proper commissioning. The last remaining tasks are to program the control system for the storage and ensure the solar and storage are integrated to work in concert.

After that, the utility will transition to day-to-day operations of the plant, which could pose a challenge as GMP has no experience operating storage on the grid. Through careful planning, consultation with experts, and deliberate self-education, GMP is hoping to maximize economic value with intelligent microgrid operations as soon as possible. Sandia National Labs will also be monitoring the project's performance, with particular attention to tracking the ISO and peak reduction revenues from the project.

GMP sought to own the project from the beginning because it is self-defined as a progressive, future-oriented utility operating in a regulatory environment that allows utilities to own generation and storage. GMP acknowledges there is a risk to owning and operating the plant because the concept is new and the technology is not yet proven in this exact context. However, the ability to capture as many value streams as possible was an alluring prospect to GMP, and, according to project representatives, served as justification for utility ownership of the asset:

"For a third-party, you could theoretically develop a PPA structure to accomplish the same thing. However, we want to own it so we can pass all the value streams and cost savings on to customers."

Finally, GMP views Stafford Hill as a gateway project on the way toward developing many more microgrids in its service territory (all managed by a centralized control system), with the intention of accommodating higher penetrations of renewable energy while enhancing service reliability.[10]

5.2.2 Microgrid Characteristics

a. **Microgrid Classification:** Utility community microgrid

b. **Location:** Rutland, Vermont

c. **Ownership Model:** Utility-owned

d. **Project Development Roles:**

   i. Owner/developer: GMP

   ii. Grant funding: DOE, State of Vermont

   iii. Vendors/other:

   - Dynapower: Smart inverters and procurement for storage
   - groSolar: Designed and installed the solar array
   - Vermont Energy Investment Corporation (VEIC): Performed community outreach and plans to design a kiosk for local students to view system performance
   - Sandia National Laboratories: Monitoring the performance

e. **Role of the Local Community:**

The City of Rutland leased the land to GMP, and the development is helping to achieve the city's goal of obtaining the highest solar capacity per capita in New England. GMP engaged in significant community outreach efforts to earn support for this project.

GMP is currently actively marketing the benefits of the project to all customers and the local community. As a utility, GMP does not engage in paid advertising, so for this project it used social media and newspaper articles to explain how the value streams from the project would impact customers and community members. GMP is proud to mention on its website that rates recently decreased by 2.5%, while renewable penetration increased in the portfolio. Project representatives noted that some customers call and want to learn everything possible about microgrids, while others only pay attention to the tangible benefits of rate decreases or reliability improvements. One GMP employee noted:

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[10] For example, if this project is a success, GMP hopes to provide different municipalities with a large-scale solar and storage emergency disconnection package to replace backup diesel generators. For all residential customers that already have solar, GMP hopes to develop a cost-effective neighborhood package to turn that solar into emergency generation by adding storage. The storage would be utility owned and have the additional benefits to GMP of reducing peak demand on the system.

"It is still so new for everyone [in the community] that they are mainly curious what it does, how will it benefit the grid and how will it benefit them—the customer. Education is key with any of this stuff. We're doing a lot of different things right now—this microgrid work is one piece of it. There's EV work going on, there's full e-home retrofit work where people can do a complete energy makeover on their homes. We are into a lot of stuff right now, and that educational piece is critical."

Finally, after hurricane Irene, grid reliability is a high priority for the local community. GMP understands that customers expect utilities to be proactive about ensuring grid reliability in emergency situations. In the words of one representative:

"In the wake of Irene in Vermont, Rutland was hit really hard—there was lots of flooding and damage. Having the ability to keep some critical infrastructure up and running during a time like that…it's priceless."

f. **Key Dates and Milestones:**

i. July 2013: Regulatory filing

ii. May 2014: Regulatory approval obtained

iii. July 2014: Construction began

iv. June 2015: Anticipated commissioning

5.2.3 Technical Components

a. **System Characteristics:**

i. DG: Solar PV, lithium ion (Li-ion), and lead-acid battery storage with a multi-port inverter. Power electronics and smart inverters enable optimization of PV and battery operations in response to weather, grid, and battery conditions.

ii. Customers: The system is grid-connected and rate-based, so all GMP ratepayers are indirect customers of the microgrid. During islanded mode, the single end-use customer is the local high school.

iii. Load and End Use: The system is normally grid-connected and serves GMP's system load. During islanded operation, the load is restricted to the local high school, which serves as a public emergency shelter. The solar and storage are sized to back up the emergency loads in the high school indefinitely. The project will also be part of the larger microgrid control system that GMP is implementing in partnership with NRG and Spirae—this system will incorporate the Stafford Hill project along with other solar and customer devices such as water heaters.

b. **Generation Capacity:**

i. Solar PV: 2.5 MW DC

ii. Li-ion battery storage: 2 MW/1 MWh

iii. Lead-acid battery storage: 2 MW/2.4 MWh

c. **Physical Characteristics:**

i. Number of buildings: The project intends to have at least the high school building as an emergency shelter and potentially surrounding neighboring residential customers.

ii. Number of metered points: None yet

iii. Use of public rights-of-way: Utility-owned generation uses existing distribution, including areas crossing public rights-of-way.

5.2.4 Operation

a. **Grid Interconnection:**

i. The microgrid is grid-connected and serves primarily local loads.

ii. Impact on utility operation and economics: All operations are controlled by the utility, and all economics are the responsibility of the utility. Costs and savings are passed on to ratepayers.

iii. Interaction with wholesale markets: Batteries participate in ancillary services market in ISO-NE.

b. **Dynamic Load Capabilities:**

Not applicable at this time; GMP has the ability to add additional islanded loads in the future, which will be managed with switches. GMP will be deploying a broader microgrid control system in the summer of 2015, which will integrate end-use devices with the Stafford Hill Project.

c. **Islanding Mode:**

i. Transfer time, duration, and protocols: During islanded mode, GMP allows electricity to flow from the project to the local high school. The school can be powered indefinitely during islanded mode.

In the future, GMP intends to add other loads that will be served during islanded mode. After testing, they will be working to include grocery stores and restaurants as potential islanding loads as well. As all loads are connected to the distribution system, it is easy for GMP to add more islandable loads. This expansion flexibility is another reason why GMP sought to own the project. Islanding capabilities at this site could be expanded without any additional cost or regulatory approval. As one GMP representative said, "It requires the placement of a few switches."

ii. History of successful attempts: The system will be commissioned in June 2015, so there is no history available yet.

5.2.5 Permissions and Regulatory Matters

The project encountered minimal issues and received all necessary regulatory approvals. GMP communicated frequently with regulators during the design phase of the project to ensure there were no surprises from the regulators' perspective. Early, frequent, and direct contact with regulatory decisionmakers was important to permitting the project. This was true not only at the state level, but at the local level for construction, fire safety, and land development permits.

GMP sought permission for construction under Section 248 of regulations, which includes a requirement for an environmental impact statement (EIS) and a cost-benefit analysis. Since the technology—in particular the large-scale storage—was new to both the utility and the regulator, the process for permitting the development was educational for both parties. The favorable and progressive regulatory environment in Vermont enabled approval. As a GMP representative involved in the regulatory process said:

"We can pick up the phone, schedule a meeting, go down, sit down, and just talk through these things [with the regulator]. [The process] is just as much educational as it is policy—and regulation—oriented."

GMP and regulators spent significant time evaluating how the facility would function and interact with the macrogrid. Ultimately, regulators and GMP were able to agree on an assessment of the value of solar and storage and demonstrate positive value to all ratepayers, thus allowing GMP to finance this project through its rate base.

5.2.6 Financial Model

a. **Total Project Cost:** $10.77 million of which $285,000 is funded by the DOE and the State of Vermont; ongoing operating costs

   Solar: $5.77 million, $2,308/kW; storage: $5 million, $1,250/kW (GMP estimates)

b. **Project Financing:**

   The microgrid is utility-owned and operated. Upfront costs for the project were paid by GMP, with costs for both solar and storage passed onto ratepayers after passing the requirements of Section 248 in Vermont state regulatory proceedings.[11] Supplementary financing for the storage was sourced through a grant totaling $285,000 from the DOE and the State of Vermont. There are some tax benefits from the project such as the Investment Tax Credit (ITC) for the solar PV and inverters. There is also a sales tax exemption for components used to generate electricity. Ongoing revenue/savings streams include:

   i. Ancillary services and frequency regulation provided to ISO-NE[12]
   ii. Peak shaving for GMP
   iii. The ability for GMP to accommodate higher penetrations of renewable energy
   iv. The ability to reenergize customer-owned PV through the distribution grid during emergencies
   v. Deferral of future transmission and distribution investments

[11] State of Vermont, Public Service Board, May 28, 2014, "Docket No. 8098." Montpelier: 2014. Available at http://psb.vermont.gov/sites/psb/files/orders/2014/2014-07/8098%20Final%20Order.pdf.
State of Vermont, General Assembly, May 28, 2014, "Docket No. 8098." Montpelier: 2014. Available at http://legislature.vermont.gov/statutes/section/30/005/00248.

[12] Regarding ancillary services, GMP is currently paid for their share of capacity they contribute to the market on the one-hour peak of the year. The capacity market is presently valued at $30 million, yet GMP expects the value to increase to $100 million within several years. The regional frequency regulation market is entirely novel, so the revenue projections from this service remain to be determined.

vi. Emergency preparedness for the community (not yet monetized)
vii. Payments from satisfied customers who increasingly demand environmentally friendly electricity

Furthermore, any remaining life in the system beyond the 25-year financing horizon will accrue as benefits to the utility and ratepayers, which is generally not available from solar resources procured through power purchase agreements.

Upfront investment and ongoing net costs/savings are rate-based and passed on to all rate-payers. At this time, there are no additional payments from local customers benefiting from islanded power, though GMP is investigating this service option.

c. Cost Recovery:

In regulatory filings, GMP has provided a range of value streams for each of these benefits, with total benefits from $350,000 to $700,000 per year in the near term. Over the long-term, GMP estimates the total value of these revenue streams at $2.8 million to $6 million. GMP estimates that the nominal levelized cost of power from the solar component over an assumed 25-year project life will be $0.171 per kWh. The value of the energy, capacity, transmission, ancillary services, and renewable energy credits (RECs) generated by the solar component will be approximately $0.187 per kWh. The value of the storage component is captured through regulation service, avoided capacity charges, avoided Regional Network Service (RNS) charges, and energy arbitrage opportunities.

d. Customer Types:

i. Primary customers:
   - *Normal operation:* Rate-paying customers located near the project
   - *Islanded operation:* Local high school in Rutland

ii. Other customers: all GMP ratepayers

e. Services Provided to Participating Customers and Corresponding Pricing Models:

During normal operation, the microgrid provides benefits to the macrogrid of peak shaving, frequency regulation, and improved resilience. The Stafford Hill solar + storage microgrid has black-start capability, so in the event of an emergency, the utility can use the energy stored in the batteries to re-energize portions of its service territory. While the ratepayers (customers) of the macrogrid do not see these benefits directly, GMP is working to educate its customers about the value streams from the project and how this project (in addition to other measures) has recently helped reduce rates by 2.5%.

During islanded operation, GMP uses the microgrid to provide emergency backup power for the local high school. Currently, this is the only islandable load for the microgrid and there is no additional price on these services; however, GMP is investigating the opportunity to include other customers within the islanding capability of the microgrid, as well as the option for these customers to pay a premium for such a service.

Other services include the following:

i. Higher quality power and precisely balanced voltage for nearby customers

ii. Black-start capability helps to reenergize local portions of the macrogrid after outages, including providing power that allows other nearby solar to redistribute energy using the GMP grid infrastructure during a large-scale outage

GMP is optimistic about its ambitious microgrid agenda due to substantial support from customers. Project representatives claim there is survey data throughout Vermont showing overwhelming support for cost-effective renewable energy developments. One representative characterized the utility's efforts as the following:

"Just like anything, there is a sloppy way to do things. You can go and deploy a ton of renewables without thinking about cost, and drive prices and rates up like crazy. Or you can take the approach we do, which is deploying renewables cost-effectively. We just had a 2.5% rate decrease at GMP while other state in New England are having 30-40% increases while we are developing and deploying all of these projects."

5.2.7 Microgrid Benefits

a. **Energy Benefits:**

i. Peak shaving

ii. ISO ancillary services for frequency regulation

iii. Energy provided to the high school during islanded operation

b. **Utility Benefits:**

i. Emergency preparedness

ii. Demonstrated ability to accommodate high penetration of renewable energy

iii. Meet customer demands of environmentally friendly electricity

iv. Deferred future transmission and distribution investments

v. Ability to reenergize the grid and other solar installations during an outage

vi. Ability to pilot and test microgrid technology to serve as model for future development

vii. Reduced line congestion and line losses

c. **Environmental Benefits:** Zero emissions from renewable energy

d. **Cost-Benefit Analysis (CBA):**

A more detailed cost-benefit analysis is available in regulatory filings. Because much of the value from this project remains uncertain, in the Section 248 filing GMP assigned a low-high range for benefits, which resulted in an overall project range from a slightly negative NPV to a decently positive NPV. These ranges were discussed at length during the regulatory process before GMP obtained approval. GMP perceives this project as having greater benefits that cannot be represented in the NPV calculation:

"When you go to build a substation because your load is growing or your reliability is not great, you don't try to do an economic benefit analysis down to the last cent. You say, 'we need this substation to feed these customers reliably and keep this level of service up.' And you do it. There is real customer value that comes out of that."

5.2.8 Lessons Learned

a. Success Factors:

Early and ongoing education of the public and support from local officials and regulators helped this project develop smoothly. By working with regulators, GMP demonstrated the value of solar and storage to the macrogrid as well as locally during outages. GMP was able to help them understand the process, avoid surprises, and work through issues. This same process applies to local permits including construction, fire safety, and land development. Local community support was strong for this project because GMP engaged the public with education efforts, and Rutland has the goal of being the solar capital of New England.

Utility ownership allows the capture of all possible value streams in one place, and the utility can pass those on to both the local and broader customer base. GMP captured many value streams in the form of cost savings, revenue increases, and customer/community satisfaction. Additionally, funding provided by DOE and the State of Vermont helped cover project costs.

b. Challenges and Recommendations:

GMP admits it should have spent more time up front reviewing the project's controls and operation protocol to ensure long storage asset life and capability for the batteries to capture all desired revenue streams. Technical constraints can have a significant effect on project economics. The control system issues were ultimately solved, but focusing on this up front would reduce project complexities. In the future, GMP plans to spend more time on designing the battery charging, dispatch, and operations to optimize system peaks, energy arbitrage, and battery life and effectiveness.

The team also related that it should have spent more time up front identifying and specifying exactly how the utility would monetarily capture all of the benefits provided by the microgrid. After reflecting on the lessons learned from the project, a representative offered this statement:

"[Effective microgrid development] is about asking: What do you want this microgrid to do? What are all the value streams you are going to extract from that? How are you going to physically set that up and control that?"

The outlook of GMP's executive leadership is unconventional compared to most utilities. Stafford Hill encountered few internal barriers to development, as GMP is pursuing a number of cutting-edge projects in demand-side management and renewable energy. GMP's executive leadership anticipates that customers in Rutland and elsewhere in their service territory will continue to demand a higher penetration of renewables on the grid, and wants to stay ahead of customer demand for solar integration. According to one GMP employee:

> ***"Customers in Vermont want to continue to go solar. We need to make sure we stay ahead of it. We don't want to ever get to the point where we have to limit…if the customer wants to go solar I don't want to ever be in the position where we have to throw up our hands and say 'we can't take anymore!' so I want to figure this all out in advance."***

5.2.9 Contacts and Sources

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