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Notice

Canton Community Microgrid

Final Report – NY Prize Stage 1: Feasibility Assessment

Submitted to:
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CANTON COMMUNITY MICROGRID - KEY OVERVIEW METRICS

Team

Lead:	St. Lawrence University
Technical Partners:	L&S Energy Hitachi Microgrids

Utilities

Electric:	National Grid
Gas:	St. Lawrence Gas

Microgrid System Design

Size:	2,755 kW
Load Served per Year:	12,996,681 kWh

DER*	Quantity	Capacity (kw)
Combined Heat & Power:	19	1,125
Photovoltaic:	10	1,630
Energy Storage Systems:	10	410
Existing Emergency Gen:	*10*	*3,269*

Microgrid Financials

Total Installed Cost:	$ 8,380,000
Net Installed Cost:	$ 6,102,000
Resiliency Savings:	$ 450,000
GHG Offset:	$ 168,000
Current Avg. Electric Rate:	$ 0.089/kWh

Supporting Organizations

Canton Potsdam Hospital	St. Lawrence-Lewis BOCES
Canton Central School District	Town of Canton
SUNY Canton	United Helpers
St. Lawrence County	Village of Canton
St. Lawrence University	

Customer Types

Gov't Administrative:	2
Emergency Services:	1
Municipal Services:	1
Education:	3
Health Care:	1
Multi-Unit Residential:	1
Total:	**9**

Electric Demand & Consumption with Microgrid

	Max kW	Avg kW	kWh / yr
Node 1	316	101	887,645
Node 2	376	181	1,588,932
Node 3	542	269	2,360,340
Node 4	599	185	1,617,373
Node 5	85	14	125,775
Node 6	687	325	2,845,768
Node 7	509	224	1,960,494
Node 8	642	180	1,580,352
TOTAL	3,756	1,480	12,966,681

Benefit Cost Analysis Outputs

	Scenario 1	Scenario 2
Days of Major Outage	0 days/yr	0.5 days/yr
Total Benefits**	$ 17,100,000	$ 21,100,000
Total Costs**	$ 20,700,000	$ 20,700,000
Net Benefits**	$ -3,610,000	$ 424,000
Benefit-Cost Ratio	0.8	1.0

***Net Present Values*

PROJECT TEAM

St. Lawrence University

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L&S Energy

- Dennis Landsberg
- Ron Slosberg
- Shawn Mackey

Hitachi Microgrids

- Erica Hauver
- John Westerman
- Steve Pullins
- Brian Levite
- Alex Rakow
- Ed Chinevere
- Michael Uhl
- Coleman Adams
- Urs Gisiger

PROJECT STAKEHOLDERS

- Canton Postdam Hospital
- Canton Central School District
- SUNY Canton
- St. Lawrence County
- St. Lawrence-Lewis BOCES
- St. Lawrence University
- Town of Canton
- United Helpers
- Village of Canton

EXECUTIVE SUMMARY

The New York State Energy Research and Development Program (NYSERDA) established the New York Prize program to stimulate adoption and deployment of community microgrids throughout the state to:

- Reduce energy costs
- Increase the reliability of the power supply and community resilience
- Promote cleaner sources of energy

This report describes the results of Stage 1 of the NY Prize Feasibility Assessment for the Canton Community Microgrid. The team of L&S Energy, Hitachi Microgrids, and St. Lawrence University developed the microgrid design according to NYSERDA's requirements and the needs and priorities of Canton stakeholders that consisted of the Canton-Potsdam Hospital, Canton Central School District, SUNY Canton, St. Lawrence County, St. Lawrence-Lewis BOCES, the Town of Canton, United Helpers, and the Village of Canton.

Community Overview

Canton is a close-knit rural community of 18,000 people located in the northern part of New York State. The Village of Canton is the population center of the town and is an attractive college community with a historic business center, two golf courses, parks, and museums. It is home to two excellent universities, St. Lawrence University, a private four-year liberal arts college, and SUNY Canton, which offers two and four year degrees. The town is also the county seat. St. Lawrence County is both the largest and one of the poorest counties in the state and, as such, Canton provides many social services to disadvantaged residents beyond the immediate community. The town, predominantly rural in character, encompasses farms, meadows, woodlands, and beautiful open spaces. It is located eighteen miles from the Canadian border in the broad St. Lawrence River plain, with the Adirondacks just to the east. Canton is a strong community where neighbors know each other and citizens are involved with their schools, churches, and other organizations. The Canton community is a typical, rural, lower to middle class community where people live and work. This represents a great opportunity to demonstrate the benefits of microgrids for a vast number of villages in New York State.

Census data identifies the area covered by the microgrid as below US median household income, with an average household annual income of $50,385 and an unemployment rate of 7.7%.

The Canton Community Microgrid design is focused on the development of an overall energy strategy that incorporates both demand-side management and new distributed generation resources to support the microgrid operational objectives. The microgrid operational objectives are to simultaneously improve resiliency, increase energy efficiency, lower emissions, and lower cost to energy users.

Community Requirements and Microgrid Capabilities

The Canton Community Microgrid is designed to meet specific needs within the community. These include the need to ensure the safety of vulnerable populations, the need to harden infrastructure against storm damage, and the need to ensure continuity of emergency operations and services.

First, the microgrid is designed to protect the safety and welfare of various populations within the village. The United Helpers assisted living center includes 48 housing units for seniors and provides every vital service to them, from healthcare to laundry and catering. The microgrid will ensure that this facility will not have to curtail care in the event of a power outage. St. Lawrence University and SUNY Canton have a combined enrollment of over 6,200 students. The microgrid will support the uninterrupted operation of dining at SUNY Canton and dining, health services, heat, and other services at St. Lawrence University. Both universities will serve as emergency shelters for the community in the case of an extended power outage.

The importance of energy resilience at these facilities is compounded by the potential for winter weather to cause outages in St. Lawrence County. Ice storms in 2013 left tens of thousands of county residents without power, many for a day or more.

In addition to the 6,700 residents of the Town and Village of Canton, the facilities within the planned microgrid serve a large population across the region. Many of these facilities will have an important role to play in emergency situations, including the Canton Fire Department and the Public Safety Building, which serve a broader regional population of around 8,000. The 94-bed Canton-Potsdam Hospital serves patients from across St. Lawrence County, a total population of about 111,000 residents. Several others facilities could serve as emergency shelters if there should be a need. The microgrid will ensure that when an emergency is associated with a power outage, the facilities involved in emergency response will remain powered and operational.

The Canton Community Microgrid is designed to address these resiliency needs with clean, efficient, and cost effective technologies and architecture. The microgrid is also designed to provide some benefit to the utility. In addition to bringing new distributed generation onto the grid, the microgrid will facilitate participation in National Grid's demand response programs, which will help the utility to cost effectively meet peak demands.

Technical Design

Analysis of the Canton Community Microgrid design indicates that the project is technically viable and meets the community's requirements with commercially available and proven technologies. The proposed design for the Canton Community Microgrid is based on the strategic placement of distributed energy resources (DER) among the included facilities. The DER in the microgrid design include solar photovoltaics (PV), natural gas powered combined heat and power (CHP), energy storage systems (ESS), and existing backup generators. (No new generators will be installed). The microgrid DER selection is based on Hitachi's *Microgrid Portfolio Approach.* This approach uses a careful analysis of energy requirements and the electric load profile of all covered facilities to determine optimal size and specification of DER. The goal of this approach is to enable microgrid resources to serve the microgrid loads more efficiently, more cost effectively, and with lower emissions per unit of energy consumed.

Under this strategy, base-load CHP will be designed to run at design output for a majority of the hours per year. All critical facility services can be provided by a set of "always-on" microgrid resources operating in conjunction with the grid for the majority of hours in a year. To meet the load that varies above the base load, PV and ESS will be integrated into the system. ESS are specified based on their capability to address PV intermittency support, PV load shifting, peak shaving (to manage utility imports), supporting CHP loading, and stabilize island mode operations. The design also incorporates active microgrid controls that enable optimal operation of energy storage, PV, and building management systems to manage load and reduce the afternoon peak load when needed.

The microgrid is designed to include critical facilities located throughout the Canton community. In order to include non-adjacent facilities, the design is based on eight separate nodes, each of which have their own microgrid resources and are able to island individually. In grid connected mode, the resources will be dispatched to meet their respective missions. The table below, summarizes the DER, new and existing, that will be included in the proposed microgrid design.

Executive Summary Table 1 - Microgrid Resources Comparison

Node	Operation Scenario	Grid	PV		Battery Energy Storage		Natural Gas Engine or CHP		Backup Generators	
		Peak kW	# of Inverters	kW	Qty	kW / kWh	Qty	kW	Qty	kW
1	Business as Usual	316	-	-	-	-	-	-	-	-
	Microgrid	160	1	60	1	25/50	3	105	-	-
2	Business as Usual	376	-	-	-		-	-	-	-
	Microgrid	170	1	220	1	35/70	2	140	-	-
3	Business as Usual	542	-	-	-		-	-	2	2,000
	Microgrid	230	1	360	1	60/120	3	170	2	2,000
4	Business as Usual	599	-	-	-		-	-	1	405
	Microgrid	360	1	90	1	25/50	3	175	1	405
5	Business as Usual	85	-	-	-		-	-	1	60
	Microgrid	57	1	40	1	15/30	1	5	1	60
6	Business as Usual	687	-	-	-		-	-	3	430
	Microgrid	240	2	380	2	130/260	4	235	3	430
7	Business as Usual	509	-	-	-		-	-	1	19
	Microgrid	230	1	380	1	100/200	1	130	1	19
8	Business as Usual	642	-	-	-		-	-	2	355
	Microgrid	467	2	100	2	20/40	2	165	2	355

Executive Summary Table 2, which also appears in Section 2 of this report, gives an overview of the normal operation of the proposed microgrid design in terms of electricity demand and consumption, thermal load, and thermal heat recovery (through new CHP systems) by node.

Executive Summary Table 2 - Microgrid Energy Overview: Grid Connected Operation

Node	Electric Demand Max (kW)	Electric Demand Avg (kW)	Electric Consumption kWh/year	Electric Consumption kWh/month	Thermal Load kBTU/year	Thermal Load kBTU/month	Thermal Recovery kBTU/year	Thermal Recovery kBTU/month
1	316	101	887,645	73,970	4,976,309	414,692	1,732,884	144,407
2	376	181	1,588,932	132,411	23,284,908	1,940,409	4,259,608	354,967
3	542	269	2,360,340	196,695	20,798,676	1,733,223	5,776,180	481,348
4	599	185	1,617,373	134,781	10,638,819	886,568	4,973,634	414,469
5	85	14	125,775	10,481	1,055,745	87,979	114,177	9,515
6	687	325	2,845,768	237,147	27,227,686	2,268,974	6,001,131	500,094
7	509	224	1,960,494	163,375	21,837,282	1,819,774	3,500,983	291,749
8	642	180	1,580,352	131,696	9,286,639	773,887	3,387,756	282,313
Total	**3,756**	**1,480**	**12,966,681**	**1,080,557**	**119,106,064**	**9,925,505**	**29,746,353**	**2,478,863**

The microgrid controller will operate the microgrid to maximize economic benefits, minimize emissions, and maximize reliability of service in the event of a fault on the grid. The microgrid controller will also track the hours of operation of each microgrid resource, and will employ a predictive maintenance strategy to schedule maintenance before any failure occurs and dispatch a technician in the event of an alarm. As the microgrid operates, a history of performance, trending, and signature analyses will develop, adding to the microgrid's ability to anticipate and avoid failures.

The ability of the Canton Community Microgrid to provide critical facilities with an uninterrupted supply of electricity and heat during power outages depends on successful transitions into and out of "island mode." Island mode refers to the mode of operation in which the microgrid disconnects from the utility grid and powers critical facilities solely from on-site resources.

The microgrid controller will manage all microgrid resources for island mode operational and performance objectives. The microgrid design ensures a seamless transition into and out of island mode operation. The microgrid controller will have the capability to provide information to the electric utility.

Financial Feasibility

The project team developed a general budget for the Canton Community Microgrid project and incorporated it into the technical model to ensure that the design meets both the technical and economic requirements of the project. This budget includes costs for engineering, permitting, capital equipment, site preparation, construction, controls, start-up, commissioning, and training. The cost associated with "site preparation" includes the addition and modification of electrical infrastructure, PCC controls, monitoring, and protection equipment. Some of these infrastructure costs may be paid to the electric utility. The estimated installed cost for this project is $8,380,000 with an accuracy of +/- 25% (within the +/- 30% set by NYSERDA). The net cost with the federal investment tax credit (ITC) that was recently extended by the US Congress is $6,102,000. This cost does not include other incentives that may be applicable to the project that will be applied during the detailed analysis in Stage 2.

The outputs of the technical modeling process described above were used to evaluate the financial viability of the proposed microgrid from two perspectives. First, the project team analyzed the financial strength of the project when deployed using the proposed third-party ownership business model. Under this model, the project is funded through outside investment and debt which is recouped through a power purchase agreement (PPA) with each facility. In addition, NYSERDA contracted with Industrial Economics, Incorporated (IEc) to perform a benefit-cost analysis. The focus of this analysis is to evaluate the societal benefit of the microgrid, including benefits from emissions reductions, cost reductions, and resilience improvements.

Business Model Financial Results: Under the proposed business model, a third party would fund all development and construction of the microgrid, own and operate the assets, and sell the energy generated from the microgrid to community customers through PPAs. The community would incur no costs to build the project and would receive all of the benefits of energy resilience during a grid outage, and improved sustainability. Community stakeholders have indicated that third party ownership of the microgrid is currently the preferred ownership structure. The current weighted electric rate of the key critical facilities included in the proposed microgrid is approximately $0.089/kWh. This low cost is primarily driven by the two universities who have negotiated attractive commodity prices for their electric supply. Based on assumed project financing costs and the 25 year contract term, the study supports a PPA electric rate with an electric cost above the current rates for the facilities in this project. This estimate does not include the award of any further grants through the NY Prize program.

Benefit-Cost Analysis Results: NYSERDA contracted with IEc to conduct a benefit-cost analysis. The project team provided detailed information to IEc to support this analysis. IEc ran two scenarios for this proposed microgrid. The first scenario modeled no power outages, and evaluated the grid connected mode of operation. The second scenario modeled the number of days (or partial days) of outage at which the costs of the microgrid would be equal to its various benefits, thus yielding a cost benefit ratio of 1. For the Canton Community Microgrid, the breakeven outage case is one outage per year for a half day duration. The cost benefit results are presented in Table 3.

Executive Summary Table 3 – Cost Benefit Analysis Results

Economic Measure	Assumed average duration of major power outages	
	Scenario 1: 0 DAYS/YEAR	Scenario 2: 0.5 DAYS/YEAR
Net Benefits - Present Value	-$3,610,000	$424,000
Total Costs – Present Value	$20,700,000	$20,700,000
Benefit-Cost Ratio	0.8	1.0
Internal Rate of Return	-0.6%	6.5%

This benefit-cost analysis differs from the financial feasibility analysis performed by the project team in several ways. In addition to the differing objectives of these two analyses, the underlying assumptions used in each also differed. A few of these differences affected the results of these analyses in significant ways, including:

- Gas rates used in IEc's benefit-cost analysis were based on a state-wide average for commercial end-use customers. The rates used in Canton's financial feasibility analysis are based on available rate data from St. Lawrence Gas, and assumptions about likely discounts associated with CHP deployments (based on experience with other New York utilities). This resulted in year 1 gas rates of $6.34 and $3.97, for the benefit-cost analysis and the financial feasibility analysis, respectively. If the estimated distributed generation rate were applied to the benefit-cost analysis, net benefits would be increased by $2.52M.
- The benefit-cost analysis derives a price for electricity based on average wholesale energy costs, whereas the financial feasibility assessment evaluates the savings to the community based on actual costs paid by community participants.
- The financial feasibility assessment incorporates the tax benefits of the Federal Investment Tax Credit, whereas the benefit-cost analysis does not. This benefit reduces the capital cost of the project by $2.27M.
- Capital replacement costs used in the benefit-cost analysis were calculated as full replacement costs, whereas the project team assumed a 'rebuild' cost that is not equal to the full cost of replacement. If the 'rebuild' costs were applied to the benefit-cost analysis, net benefits would be increased by $142,000.
- The period of analysis in the benefit cost analysis is 20 years and the third party ownership model is based on a period of analysis of 25 years.

The entirety of the IEc analysis can be found in Appendix D of this report.

Conclusions and Next Steps

The NY Prize feasibility assessment indicates that the Canton Community Microgrid is technically viable and is potentially economically viable with additional NY Prize grants. As a rural, lower income community, Canton is especially well positioned to yield lessons for the rest of New York State and beyond. The project team believes that the proposed microgrid design will serve as a leading example for New York and will be beneficial and replicable to hundreds of other communities across the State and beyond. The feasibility assessment yielded several key findings:

1. ***Engaged Stakeholders*:** The Canton Community Microgrid is built around a set of facilities and institutions that are well established, and committed to the project. There are two universities among this group. This is a unique characteristic of the Canton project, and presents unique opportunities and challenges. The universities in the Canton Community Microgrid have the largest loads, and the lowest cost of electricity. This sets a very high bar for the microgrid business model, in terms of matching this rate and still covering costs.
2. ***Remote Net Metering Projects***: Several stakeholders in the Canton Community Microgrid are considering remote net metering projects. These PV installations affect microgrid sizing and economics. Although the projects may represent an attractive financial opportunity for the stakeholders involved, they will not improve energy resilience, as the microgrid would,

because they are not designed to provide islanding capability to the facilities and are not co-located at the facilities that they support.

3. ***Natural Gas Costs***: The cost of natural gas for CHP is not firm. The estimate that the project team used for the financial analysis was made using available data from St. Lawrence gas and assumptions based on distributed generation discounts from other New York utilities. However, going forward, the project team will need to work closely with St. Lawrence Gas to establish a final, firm natural gas rate for the CHP installations included in the microgrid plan.
4. ***Community Microgrid Financing Costs***: The cost of project financing is high for community microgrids. This is due to the fact that there are numerous stakeholders and potential customers, and that each stakeholder has its own procurement requirements. The project team will need to seek out a financier that is knowledgeable about these projects, and can help keep transaction costs to a minimum.
5. ***Financial Prospects:*** As it stands, the Canton Community Microgrid project is not likely to meet the financial requirements for third party financing and ownership. In order to meet these requirements, one or more of the following conditions would need to be met:
    a. The award of Stage 2 and Stage 3 NY Prize grants from NYSERDA
    b. The inclusion of additional commercial customers with higher electric costs
    c. The use of PPA rates above the current average cost of energy for prospective microgrid customers.

Based on the findings of this feasibility analysis, there are several next steps for the project team to undertake. First, the project team should solicit confirmation from each stakeholder that they are interested in continuing to participate in this effort to build a community microgrid. The team may also consider identifying additional facilities that may be good candidates for design consideration based on their criticality and potential to improve project economics. Based on the final customer list, the project should be remodeled to estimate the technical and economic impact of any additions or subtractions.

Once the model is final, the project team will need to make a go/no go decision about moving forward. If a decision is made to move forward, a project team will need to be finalized. This team will draft a proposal to NYSERDA to compete in Stage 2 of NY Prize. This Stage 2 funding will help defray the additional cost and risk associated with a multi-stakeholder community microgrid. A Stage 2 will require cost share, and a determination should be made about which parties will assume this cost.

Canton Community Microgrid
Final Report – NY Prize Stage 1: Feasibility Assessment

TECHNICAL DESIGN

The proposed microgrid solution will focus on community resiliency based on distributed resources co-located at or near the critical facilities serving the community emergency response, medical needs, and elderly and student populations of Canton. The strategy is to develop a community microgrid that consists of multiple site-specific microgrids that that may or may not be connected from an electrical perspective but are controlled as a single entity. One of the challenges of community microgrids is that the facilities and the microgrid resources are distributed. To maximize the economics, reliability, and emissions reduction potential of the community microgrid, the microgrid controller architecture must have the capability to coordinate and control different groups of resources as well as provide control for localized operations.

Initially, about 60 facilities were identified for potential inclusion in the microgrid. A screening process was developed and implemented to select the best sites for the microgrid based upon a set of screening criteria.

The proposed microgrid will include two universities (St. Lawrence University and SUNY Canton) government support services, a fire station, water system pumping, a medical facility, the local high school and middle school, as well as an elderly care facility. Collectively, there are a total of 8 “nodes” that make up the Canton Community Microgrid. The eight Canton nodes and included facilities and functions are presented in Table 4.

Table 4 – Overview of Microgrid Nodes

Microgrid Node #	Facilities	Functions
1	• Potsdam Hospital (EJ Noble)	• Medical Services
2	• Canton Central School (High School and Middle School)	• Education • Shelter
3	• SUNY Canton Dining Hall • SUNY Canton Athletic Facility	• Education • Food Service • Shelter
4	• United Helpers	• Senior housing and services
5	• Canton Fire Department • Wastewater Pumping Station	• Fire and emergency services • Municipal Services
6	St. Lawrence University: • Augsbury Physical Education Center • Newell Field House • Health and Counseling Center	• Education • Medical • Shelter
7	St. Lawrence University: • Student Center • Heating Plant • DANA Dining Center • Facilities Operations • Vilas Hall	• Education • Shelter
8	• County Courthouse Complex • Public Safety Building	• Fire and Emergency services • Public Safety • Administrative Services • Emergency Response Center

The utility feeders are mainly overhead lines, which cannot be relied upon in the event of a major storm. The microgrid design employs underground cabling to support each microgrid node in key areas where it is cost effective for the overall project. While this greatly improves resiliency within a microgrid node, the cost of the underground cabling limits the reach of the node. The same general protection schemes are employed in each microgrid node as are used in utility distribution networks. Some pole-top transformers will be replaced with pad-mount distribution transformers, and additional isolating switches and breakers will be added at the PCC as described above.

The Village of Canton is supplied with electricity through multiple feeders from two substations State Street and Little River. The State Street substation is a 23 kV substation served from one 23 kV source. Two of the State feeders that will support the microgrid are 23 kV/4.8 kV. The Little River substation is a 115 kV substation served from two different 115 kV sources. Two of the Little River feeders are 115 kV/13.2 kV feeders with portions stepped down to 4.8 kV.

The feeders serving the proposed microgrid do not have a distribution automation scheme other than the operation functionality programmed internal to the breakers. Feeders are connected for adding or dropping branch circuits or individual customers via manually operated disconnects. Any operation of these disconnects would be through National Grid's CRCC and performed by National Grid operators. There are a variety of primary fuses on these feeders. All branch circuits have protective fusing rated for the individual branch loads.

The State Street substation is being retired due to asset condition. A project to retire State Street substation is expected to be completed by 2020. The load on the State Street substation will be placed on the Little River substation and will remain at 4.8 kV and the load will be carried by step-down ratios on the Little River substation. The State Street retirement project is subject to change.

The design team met with a National Grid distribution engineering team to review utility infrastructure that impacts the microgrid design. In general, they understand the proposed design and did not identify any major issues. In addition, the team met with St. Lawrence Gas to review the potential new gas loads associated with the CHP. They indicated that these new loads did not represent any new constraints on their distribution system but minor customer delivery upgrades may be required. This will be addressed in the Stage 2 detail design study.

In addition to the potential facilities identified above, the Canton Community Microgrid will create benefits for other stakeholders. If selected for the next stage of NY Prize, the project team will continue to solicit their advice and participation. These stakeholders include:

Table 5 – Community Stakeholders to Benefit from the Microgrid

Organization	Benefits from Canton Community Microgrid
National Grid	By serving the local load and providing resilient energy, the system will allow the utility to delay potential investments in the existing substation equipment. Microgrid facilities that are operational can be used to support National Grid restoration works who are working remotely through providing shelter, food, and showers.
St. Lawrence Gas	Installing additional natural gas generators will create new demand for St. Lawrence Gas, and will support natural gas infrastructure upgrades in the Canton area.
Town of Canton	The microgrid is a critical element in the development of a community-wide emergency preparedness program whereby the 11,321 residents of the town are provided options for shelter, food, medical services, and emergency response services in the event of an extended outage to the area.
Village of Canton	The microgrid is a critical element in the development of a community-wide emergency preparedness program whereby the 6,714 residents of the village are provided options for shelter, food, medical services, and emergency response services in the event of an extended outage to the area.

Key Features of the Microgrid

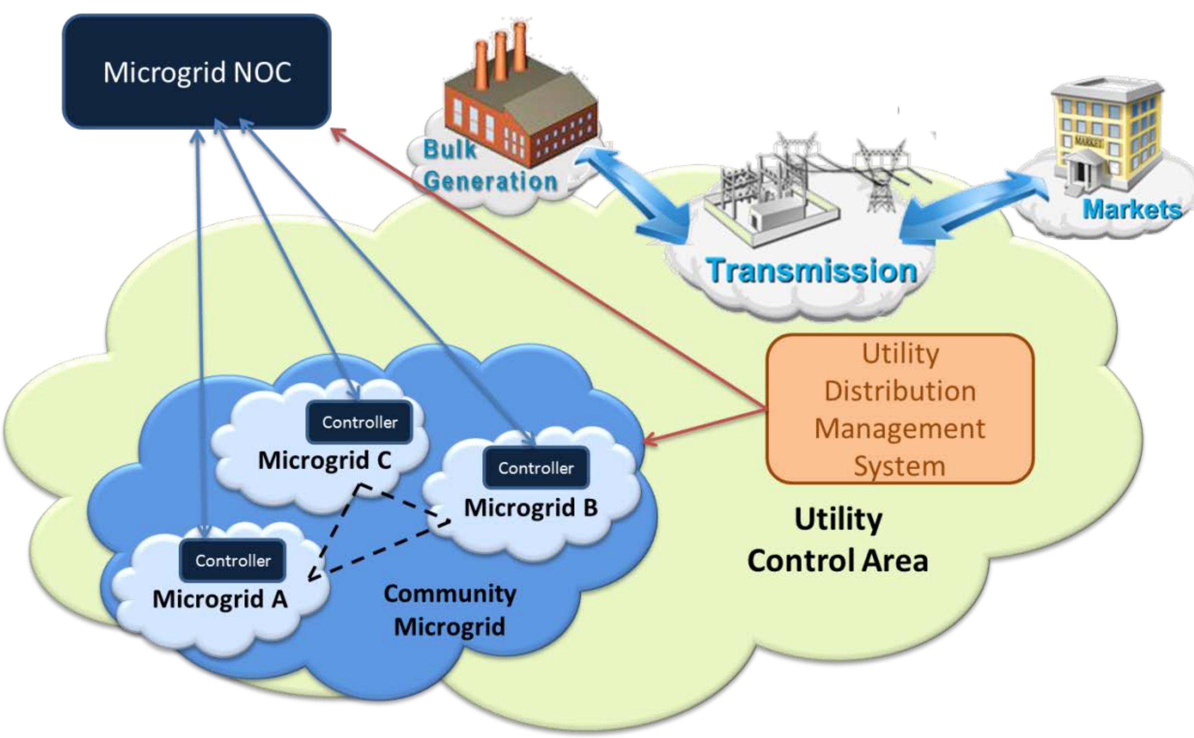
Community Microgrid Controller

One of the challenges of community microgrids is that the facilities and the microgrid resources are distributed. To maximize the economics, reliability, and emissions reduction potential of the community microgrid, the microgrid controller architecture must have the capability to coordinate and control different groups of resources as well as provide control for localized operations.

Our team has developed a project concept for the community microgrid that allows for simultaneous control of multiple microgrids in the community as well as coordination with the local utility. Specifically, the solution includes local controllers in each microgrid part as well as a hosted controller in the Microgrid network operating center (NOC) that can operate each microgrid part separately or collectively.

In the grid-connected mode, the primary operations will focus on maximizing economic benefits and minimizing emissions across all the microgrids within the community. In some cases, the aggregation of the microgrid resources can be leveraged to support utility firming request and/or RTO/ISO ancillary services such as demand response and frequency regulation. However, during a reliability event, the operation of each individual microgrid controller will focus on the load and generation assets only within its control. The local controller will transition to island mode while maintaining proper voltage and frequency. Figure 1 presents our team's design approach for the community microgrid controller architecture.

Figure 1: Project Concept for Community Microgrid



The microgrid controller will have an active management and control architecture that supports the 10 EPRI/ORNL Use Cases:

1. **Frequency control**: In normal operations, the microgrid may not have enough resources to affect frequency on the grid. It could participate in the ancillary services markets by increasing output to support the frequency in the local grid, but total impact would be small. Nevertheless, the system will monitor frequency along several thresholds, providing a discrete high-low range; the system will detect if frequency is out of range and respond by taking resources off-line or dispatch other resources to manage frequency. Also, the system will analyze data to detect subtler trends that do not exceed thresholds but provide evidence of a possible problem.
2. **Voltage control**: In both grid-connected and islanded modes, the voltage control application will be used to provide stability to the microgrid and connected circuits. Voltage control leverages line sensing and metering to provide control actions when necessary. This application will take into account traditional volt/VAr instruments such as tap changers and cap banks along with inverter-based resources, which should provide a greater degree of optimization.
3. **Intentional islanding**: For each microgrid node, the islanding process will be semi-automatic so that a utility operator or local energy manager will be able to move through each step before opening the PCC. The utility operator will provide the appropriate permissions for opening the PCC. The local microgrid controller for each microgrid node will be responsible for setting the voltage source and load following resource.
4. **Unintentional islanding**: The designed PCC structure, coupled with additional analysis compliant with IEEE 1547.4, enables the utility-controlled breaker or switch to immediately open (frequency = 59.3 Hz) on loss of the grid. The microgrid managed synchronizing breaker will remain closed for a few more milliseconds until microgrid frequency reaches 57.0 Hz. Since the inverters and generator controls are keying off the synchronizing breaker, these few additional milliseconds enable the energy storage and power electronics to better manage the transient as the microgrid resources pick up the portion of the load served by the utility grid just before the grid was lost. When, or if, the frequency dips to 57.0 Hz and the synchronizing breaker opens, the microgrid will move into island mode. The microgrid controller will adjust all microgrid resources for the new state and island performance objectives.
5. **Islanding to grid-connected transition**: As with intentional islanding, the utility operator will provide the appropriate permission to close in the PCC. The local microgrid controller will support the reconfiguration of each dispatchable resource.
6. **Energy management**: The microgrid design incorporates a portfolio of resources. The EPRI Use Case takes a traditional energy management approach– economic dispatch, short-term dispatch, optimal power flow, and other processes typical in utility control room environments. The microgrid controller will have corresponding applications that manage a set of controllable generation and load assets. Within that portfolio, the system will also optimize the microgrid based on load forecast, ancillary services events, changes in configuration, outage of specific equipment, or any other kind of change to determine the optimal use of assets 48 hours ahead.

7. **Microgrid protection**: The microgrid controller will ensure two primary conditions. The first is that each protection device is properly configured for the current state of the microgrid, either islanded or grid-connected. The second condition is that after a transition, the microgrid controller will switch settings or test that the settings have changed appropriately. If the test is false in either condition, the controller will initiate a shutdown of each resource and give the appropriate alarm.
8. **Ancillary services**: The controller will provide fleet control of the nested microgrid parts. Specifically, the utility operation will have the ability to request and/or schedule balance up and balance down objectives for the fleet. The cloud-based controller will take the responsibility to parcel out the objectives for each microgrid part based on the available capacity.
9. **Black start**: The local microgrid controller will provide a workflow process for restarting the system. Each microgrid part will have a unique sequence of operations for predetermined use cases. One objective will be to provide this function both locally and remotely to meet the reliability requirements of the overall design.
10. **User interface and data management**: The solution provides local controllers in each microgrid part as well as a hosted controller that can operate each microgrid part separately or collectively. The primary actors are the utility operator, local energy managers, maintenance personnel, and analyst. The user experience for each actor will be guided by a rich dashboard for primary function in the system around Operations, Stability, Ancillary Services, and Administration.

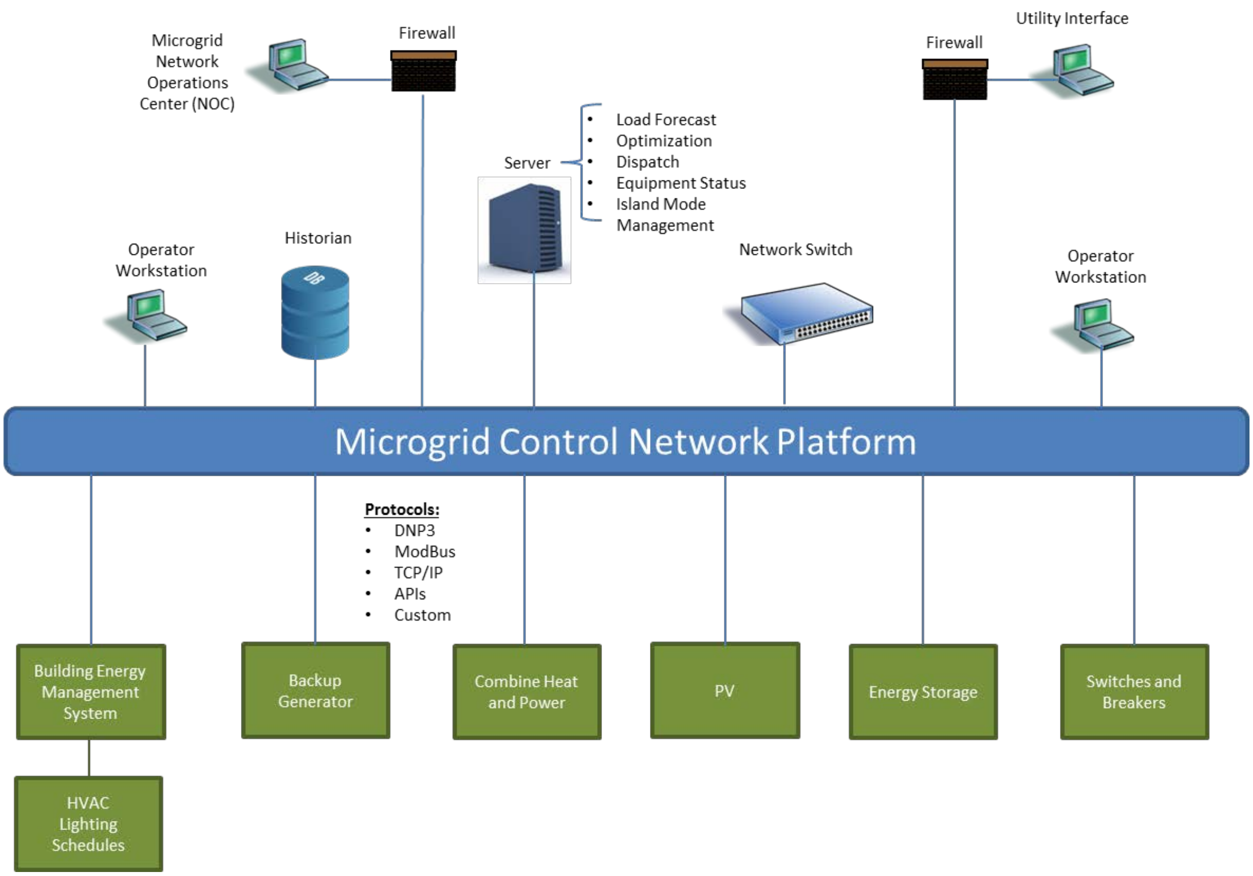
In addition, the microgrid controller will:

- Forecast variable aspects: load, wind, solar, storage
- Dispatch of DER to maximize economic benefit
- Continuously monitor and trend health of all system components
- Take into account utility tariffs, demand response programs, and ancillary service opportunities
- Understand operational constraints of various DER and vendor-specific equipment
- Interface to local utility
- Meet rigid and proven cyber security protocols

Ultimately, the control system will perform all of the functions above to continuously optimize the operation of the microgrid for economic, resiliency, and emissions performance.

A microgrid controller design needs to be reliable and have redundancy comparable to the other microgrid resources. A standard controller approach such as central controller or PLC design will therefore not be sufficient. The architecture must support the capability to interface with field devices, provide a platform for communications and data management, provide for both local and remote operator access, have a data historian, and provide for applications to meet the microgrid Use Cases highlighted above. A conceptual controller topology is presented in the Figure 2.

Figure 2 – Conceptual Microgrid Controller Topology



To support the community node approach, the microgrid control scheme will provide for a secure external access to the NOC that can coordinate the various nodes within the community. In addition, remote access to the utility will be provided to inform them and their distribution operators of the microgrid status and to communicate protection relay permissions for the island-mode transitions. The system will be designed so the core control functions are located within the microgrid and so that loss of communication with the NOC will not significantly impact the local operations of any node. The NOC monitors equipment performance and coordinates across nodes. In the event of an outage, all control will move to local controllers and focus on site specific optimization and operations.

The microgrid controller will leverage existing equipment to the greatest extent possible. This will include building energy management systems, backup generators, and local area networks. For the purposes of reliability and security, the microgrid control system will consist of new and independent infrastructure.

Telecommunications Infrastructure

Each microgrid node will have a wireless LAN specific to the microgrid, powered by microgrid resources, and extended to every resource, device, sensor, and load interface (e.g., building management system). This communications infrastructure will be designed with dual-redundant access points to ensure reliable onboard communications.

The architecture will conform to requirements established by the SGIP and generally accepted communications protocols, such as ModBus (TCP/IP), DNP3 (TCP/IP), and IEC61850, as well as field networks for buildings such as LonWorks and BACnet. ModBus will be used throughout the microgrid nodes for communications, as it is currently the most prominent communications protocol within the DER and inverter community. Communications with the utility distribution management systems will use DNP3, as that is the prominent protocol used by the utility industry.

In addition, the NIST IR 7628, “Guidelines for Smart Grid Cyber Security,” will be followed in the architecture and design of the microgrid controls’ IT and communications to ensure security and continuity of operations in all modes. Finally, the IT/telecommunications infrastructure will be new to secure the microgrid controls network separately from existing IT and communications systems at the facilities.

Communications – Microgrid and Utility

Communications between the microgrid and the utility will occur in two forms: (1) utility DMS will interface with the microgrid controls for monitoring and managing the PCC utility-controlled isolating switch and microgrid-controlled synchronizing breaker, and (2) a dashboard served by the microgrid controls to the utility via the internet will give the utility insight into the day to day operations of the microgrid.

In accordance with the EPRI/ORNL Microgrid Use Case 4, the microgrid will transition into island-mode operations upon loss of communications between the utility DMS and the microgrid, assuming loss of grid. No specific microgrid action will be taken on loss of the utility dashboard service via the Internet.

The microgrid control system will be local to the microgrid node in a secure, conditioned space, (e.g., electrical room) in one of the critical facilities within the microgrid node. This ensures that real-time control of the microgrid resources and loads will be maintained in the event of a loss of communications with the utility DMS and Internet services. Although economic optimization will be reduced for a period of time, the reliability and resiliency optimization will be maintained because those algorithms are in the microgrid control system local to the microgrid node and do not require off-board communications to function.

The onboard communications within the microgrid LAN will be a dual-redundant architecture, where every LAN access point is backed up by another access point.

DISTRIBUTED ENERGY RESOURCES CHARACTERIZATION

A variety of generation sources are planned for the community microgrid. They include the following:

- CHP
- PV
- ESS
- Building Load Control
- Energy Efficiency Measures (EEMs)
- Utility Grid
- Backup Generators

The Canton microgrid design is focused on the development of an overall energy strategy that incorporates both demand-side management and new distributed generation resources to support the microgrid's operational objectives. During operation in the grid-connected mode, the resources will typically be dispatched in an economic optimization mode. This approach will ensure that the microgrid will operate in a manner that the energy delivered to the critical facilities is at or lower than that the cost of electricity that could be purchased from the local utility. In this scenario, the CHP will operate in a constant output mode at its maximum efficiency and lowest emissions, the PV generation profile will be taken into account, the energy storage will operate in a manner to maximize microgrid benefits, and the grid will operate in a load following mode. The connection to the grid will also be used to manage the voltage and frequency of the microgrid.

The microgrid will take advantage of DER to remain in operation when the utility grid is not available. The microgrid controller will monitor island mode frequency and voltage and adjust equipment operation accordingly to maintain circuit stability. Existing backup generators will be leveraged to support island operations in conjunction with the new DER. New DER will minimize the need for the backup generator operation to minimize natural gas and diesel fuel usage. The microgrid will also support the transition back to the grid when the utility service is restored. The design ensures that the return to the grid is a seamless transition and is coordinated with the utility through appropriate protocols, safety mechanisms, and switching plans (to be communicated to the microgrid controller by the utility distribution management system).

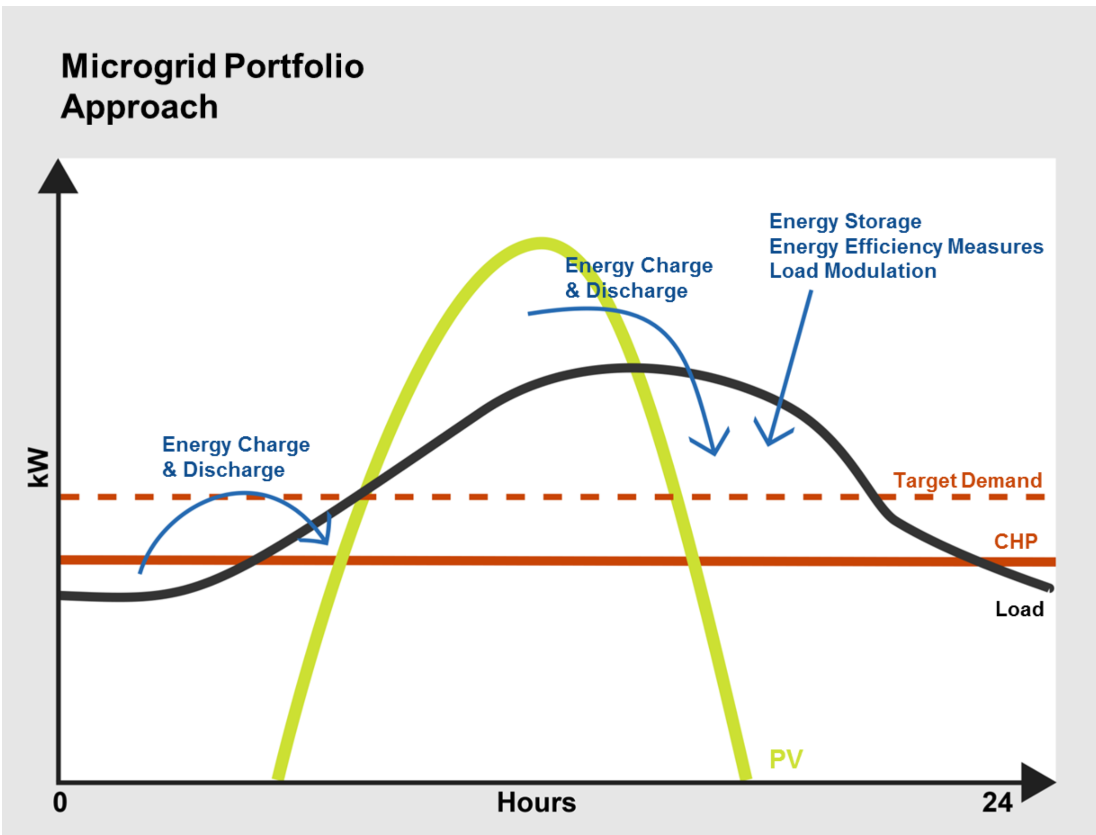
To support steady-state frequency requirements, as well as the ANSI 84.1-2006 standard voltage requirements and to support the customer power quality requirements at PCC, the microgrid controller will actively manage the dispatch of generation resources; actively manage the charge and discharge of energy storage; provide observability of microgrid-wide telemetry including frequency, power factor, voltage, currents and harmonics; provide active load management; and provide advance volt-VAr variability algorithms and other stability algorithms based on steady state telemetry of the system.

Normal and Emergency Operations

The microgrid DER selection is based on our *Microgrid Portfolio Approach* that focuses on energy requirements and a close match to the electric load profile of all covered facilities. The peak demand for critical facilities in the community occurs only a few hours per year. This means all critical facility services can be provided by "always-on" microgrid resources for the majority of hours in a year without over-building. The goal of this approach is to enable microgrid resources to serve the microgrid loads more efficiently, more cost effectively, and with lower emissions per unit of energy consumed.

Under this strategy, base-load CHP will be designed to run at design output for at least 8,000 hours per year. To meet the load that varies above the base load, resources such as PV and energy storage will be integrated into the system. Energy storage systems are specified based on their capability to change their output rapidly and address the ramp rate issue to support load following, and buffering the differences between CHP, electrical load, and PV throughout the day. This concept is presented in Figure 3.

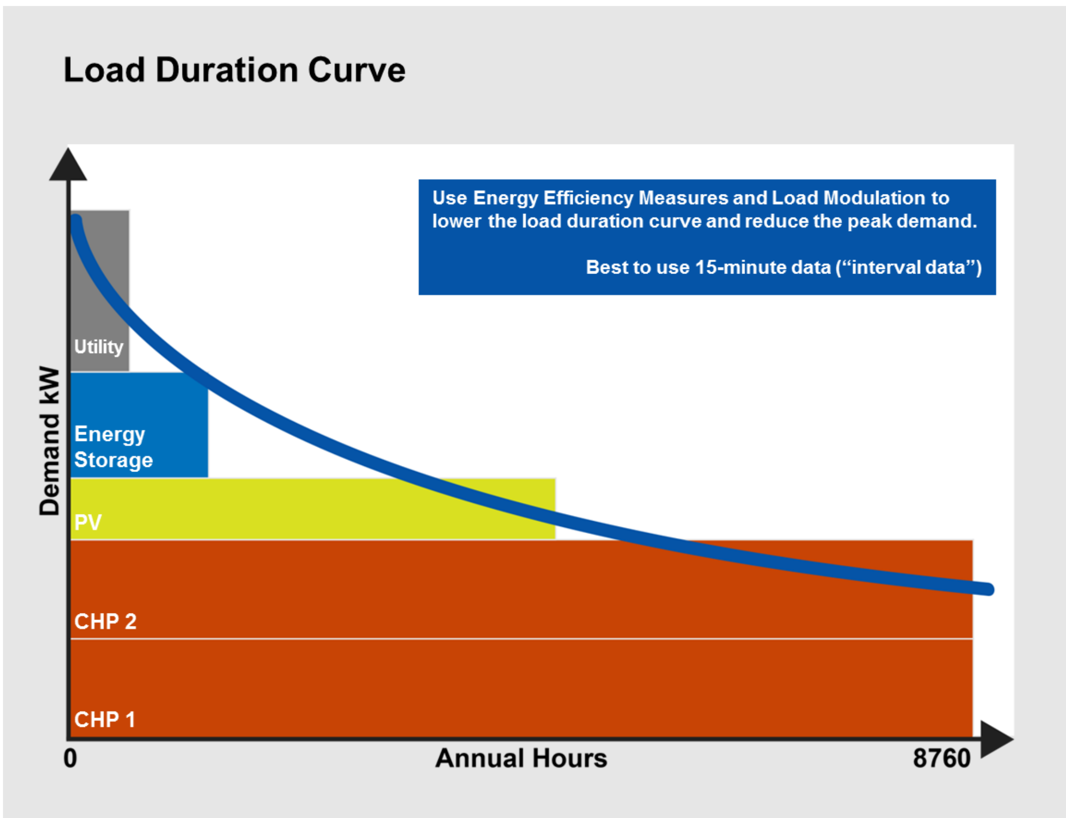
Figure 3 – Microgrid Portfolio Approach



From a long-term operations and maintenance standpoint, the Portfolio Approach enables the microgrid to operate energy resources within their design envelope. This keeps maintenance costs and fuel costs at a minimum, and helps to lower the total cost of ownership. The design also incorporates active microgrid controls that enable optimal operation of energy storage, PV, and building management systems to manage load and reduce the afternoon peak load when needed.

The load duration curve presented in Figure 4 illustrates another element of the resource selection and sizing strategy for the Canton microgrid. When operating in a grid-connected mode, the microgrid uses the grid as a resource to meet intermittent peak demand periods. When operating in island mode, the microgrid supply and demand will be managed through the dispatch of microgrid generation resources, load management, and to a minimum extent, the use of existing backup generation. This methodology allows the designers to evaluate the appropriate balance of grid service, generation resources, and load management capabilities, and provide both a technical and economic solution.

Figure 4 – Load Duration Curve



One of the most important attributes of the Canton Community Microgrid will be the ability to operate when the utility grid is not available. The methods of transitioning into an island mode are characterized as either a (1) planned transition or (2) unplanned transition.

- Planned Transition*:* In a planned transition, outside information is used to ramp up resources so there is zero grid import to the microgrid. A seamless transition occurs into island operations at the appropriate time. Outside information includes weather forecasts, grid frequency deviations, local voltage sags, or other information provided by the utility.

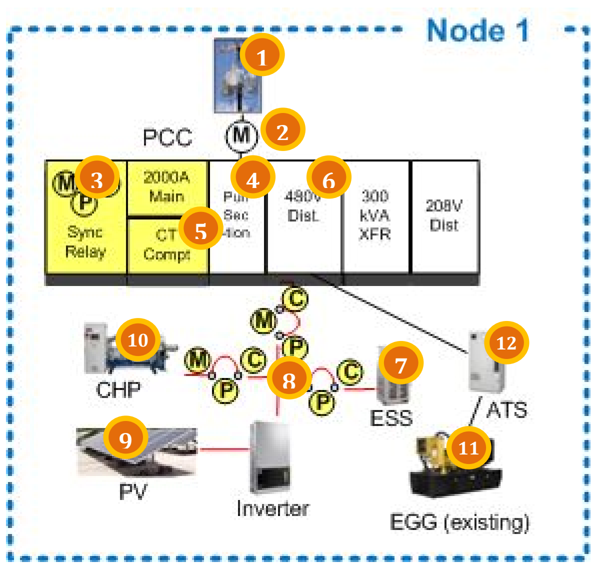
- Unplanned Transition*:* In an unplanned transition, an unanticipated outage takes place such as the loss of a transformer or a car hitting a distribution power pole. Depending on the microgrid resources operating at the time, an outage may take place that requires the microgrid to establish itself through a black start sequence of operation.

A complete layout of the design showing all microgrid nodes is presented in Appendix A. This geospatial image shows the facilities and location of electrical infrastructure and major new microgrid resources. More details about each individual node are presented on the following pages.

In addition, a microgrid one-line diagram is presented in Appendix B. The diagram includes the substation, major electrical equipment, and the rated capacity for each microgrid distributed energy resource. The PCCs are shown with associated monitoring (M), control (C), and protection (P) devices.

Figure 5 provides a brief explanation of the elements included in the one-line diagrams.

Figure 5 – One-Line Diagram Explanation



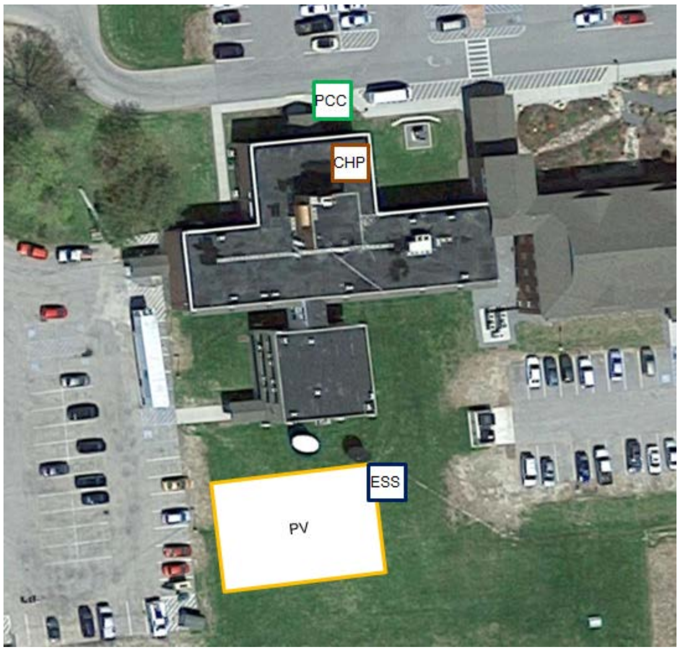
1. Transformer to the critical facility
2. Utility meter
3. Synchronizing relay controls / main breaker with monitoring, protection relays, and controls
4. Main disconnect (pull section)
5. Instrument current transformer compartment
6. Main 480V 3-phase distribution panel; step down transformer and 208 V 1-phase distribution panel
7. Energy Storage System with Monitoring (M), Control (C), and Protection (P)
8. New 480 V 3-phase cable (red)
9. Solar PV array and associated inverter
10. Combined Heat and Power system with Monitoring, Control, and Protections
11. Emergency generators: EGG (natural gas) or EDG (diesel)
12. Automatic transfer switch (ATS)

The following pages highlight the layout design and one-line diagram subsection for the eight nodes as well as a brief explanation of included energy resources.

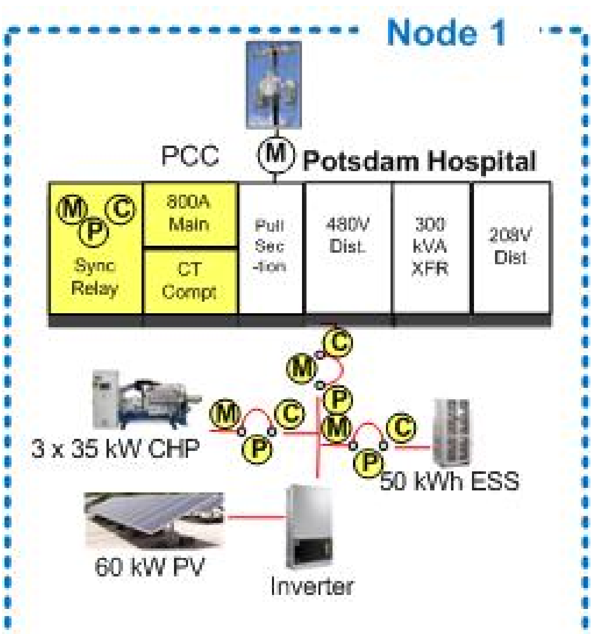
Geospatial Diagrams and One-Line Subsections

Node 1 System Configuration

Geospatial Diagram



One-Line Diagram



Facility

- Canton Potsdam Hospital: EJ Noble Facility

Description

Node 1 is a single facility node. The PCC will be located north of the building.

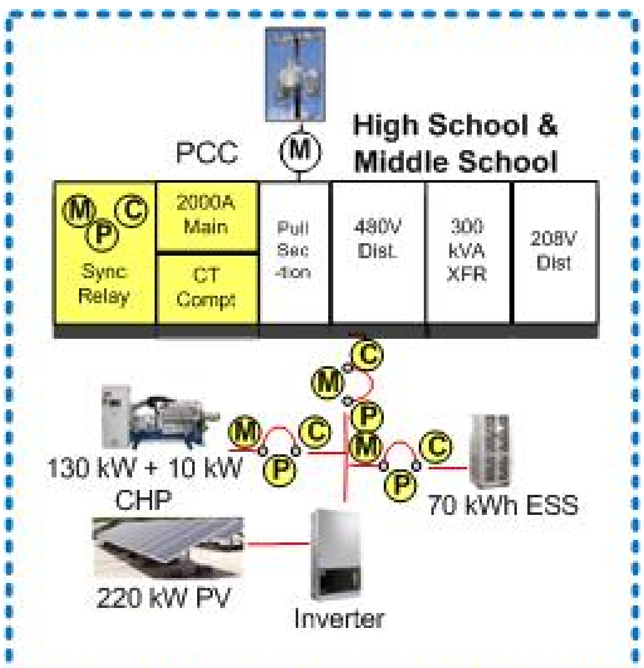
As part of the microgrid, the following will be installed:

- **PV (60 kW):** A ground-mounted PV system will be installed south of the building.
- **CHP (105 kW):** Three 35 kW units will be placed inside the building.
- **ESS (50 kWh):** An ESS unit will be co-located with the ground mount PV.

Node 2 System Configuration

Geospatial Diagram

One-Line Diagram



Facility

- Canton Schools (High School & Middle School)

Description

Node 2 contains the Canton Central Schools. The PCC will be located east of the building. 1,320 ft. of underground cable will connect the node from the nearby substation to the PCC.

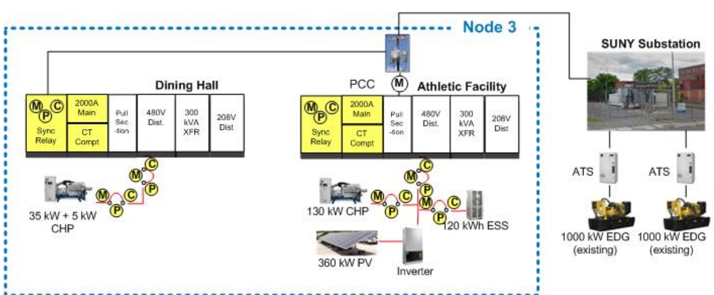
As part of the microgrid, the following will be installed:

- **PV (220 kW):** A combination of rooftop and ground-mounted PV will be installed.
- **CHP (140 kW):** 2 CHP units (130 kW & 10 kW) will be placed inside the building.
- **ESS (70 kWh):** An ESS unit will be co-located with the ground mount PV.

Node 3 System Configuration

<u>Geospatial Diagram</u>

<u>One-Line Diagram</u>



<u>Facility</u>

- SUNY Canton Athletic Facility
- SUNY Canton Dining Hall

<u>Description</u>

Node 3 contains a subset of facilities at SUNY Canton. It includes existing emergency diesel generators (2000 kW) at the new substation. The PCC will be located east of the athletic facility.

As part of the microgrid, the following will be installed:

- **PV (360 kW):** A large covered parking installation will be installed in the lot east of the athletic facility.

- **CHP (130 kW):** A CHP unit will be placed at the athletic facility.

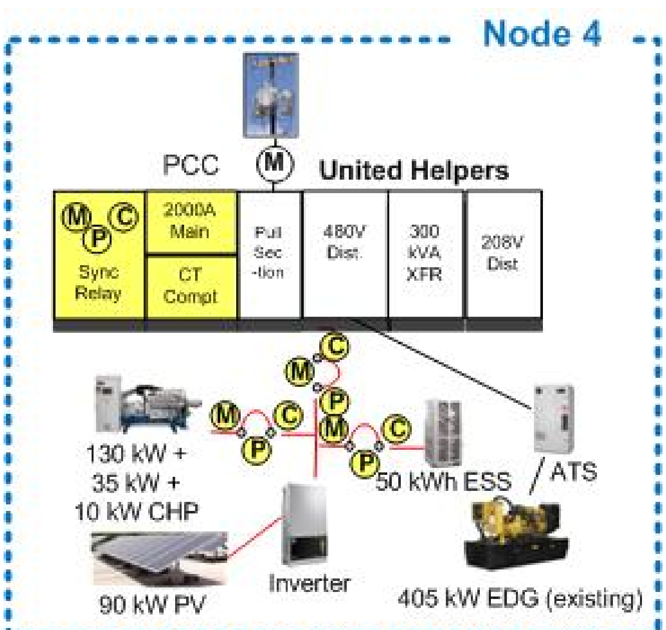
- **CHP (40 kW)**: Two small CHP units (35 kW & 5 kW) will be placed adjacent to the dining hall.

- **ESS (120 kWh):** An ESS unit will be co-located with the covered parking mounted PV.

Node 4 System Configuration

Geospatial Diagram

One-Line Diagram



Facility

- United Helpers

Description

Node 4 contains the United Helpers senior housing and services. It includes an existing emergency diesel generator (405 kW). The PCC will be located east of the facility.

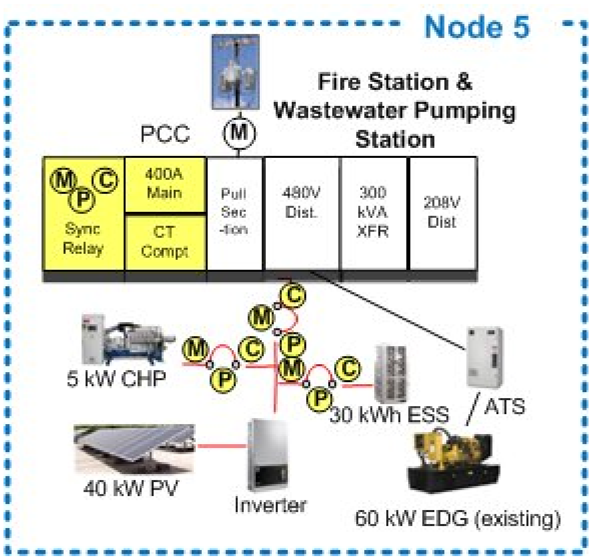
As part of the microgrid, the following will be installed:

- **PV (90 kW):** Ground-mounted PV will be installed north of the facility.
- **CHP (175 kW):** 3 CHP units (130 kW, 35 kW, & 10 kW) will be placed adjacent to the facility.
- **ESS (50 kWh):** An ESS unit will be placed inside the facility near the electrical room.

Node 5 System Configuration

Geospatial Diagram

One-Line Diagram



Facility

- Fire Station
- Wastewater Pumping Station

Description

Node 5 includes an existing emergency diesel generator (60 kW). The PCC will be located north of the facility.

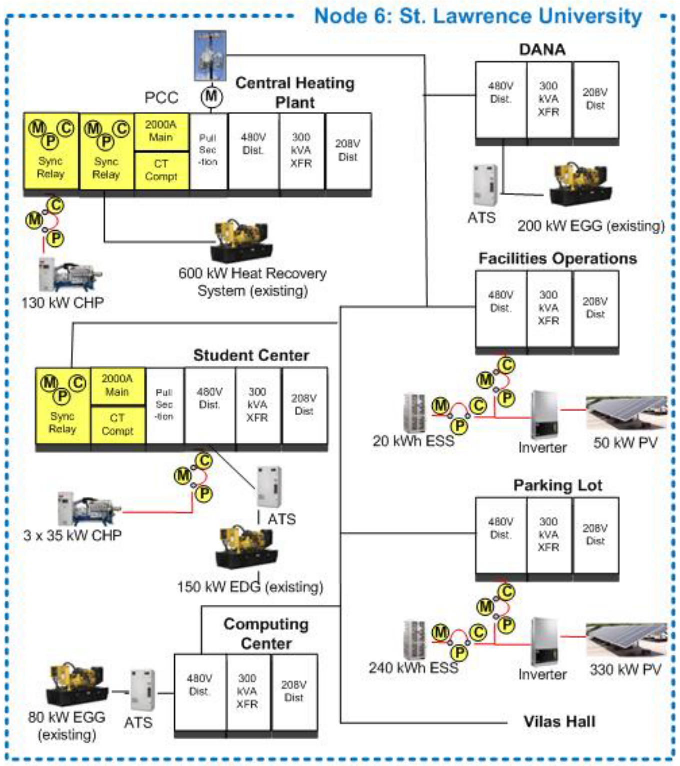
As part of the microgrid, the following will be installed:

- **PV (40 kW):** Rooftop PV will be installed at the fire station.
- **CHP (5 kW):** A small CHP unit will be placed adjacent to the facility.
- **ESS (30 kWh):** An ESS unit will be placed inside the facility near the PV inverters.

Node 6 & 7 System Configuration

Geospatial Diagram

One-Line Diagram



Node 6 Facilities

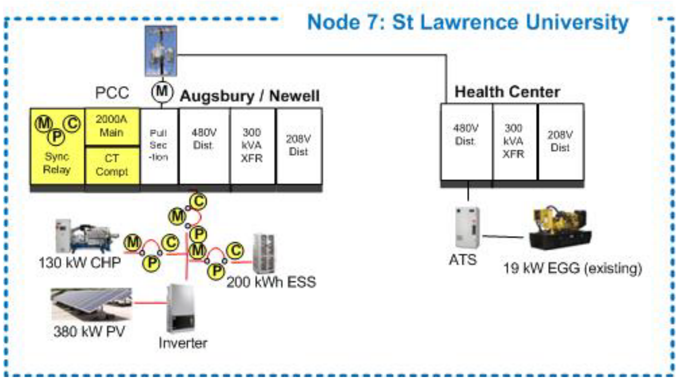
- Student Center
- Heating Plant
- DANA
- Facilities Operations
- Vilas Hall

Description

Node 6 consists of a subset of facilities at St. Lawrence University. It includes three existing emergency generators totaling 430 kW. The PCC will be located west of the central heating plant.

As part of the microgrid, the following will be installed:

- **PV (330 kW):** A large covered parking installation will be installed at the lot east of campus.
- **PV (50 kW):** Ground-mounted PV will be installed south of Facilities Operations.
- **CHP (105 kW):** Three 35 kW CHP units will be installed adjacent to the Student Center.
- **CHP (130 kW):** A second CHP unit will be installed inside the Central Heating Plant.
- **ESS (240 kWh):** An ESS unit will be co-located with the covered parking PV.
- **ESS (20 kWh):** An additional ESS unit will be co-located with the ground-mounted PV.



Node 7 Facilities

- Augsbury
- Newell
- Health Center

Description

Node 7 consists of a subset of facilities at St. Lawrence University. It includes an existing emergency gas generator (19 kW) at the Health Center. The PCC will be located east of Augsbury at the road.

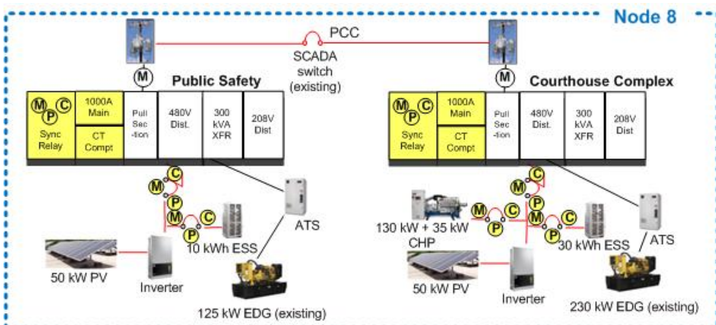
As part of the microgrid, the following will be installed:

- **PV (380 kW):** A combination of rooftop and ground-mount PV will be installed at Newell.
- **CHP (130 kW):** A CHP unit will be installed northeast of Augsbury.
- **ESS (200 kWh):** An ESS unit will be co-located with the ground-mounted PV.

Node 8 System Configuration

Geospatial Diagram

One-Line Diagram



Facilities

- Courthouse Complex
- Public Safety Building

Description

Node 8 contains two existing emergency diesel generators totaling 355 kW. The PCC will be located south of the Public Safety Building. These two facilities are fed by different substations but have an existing interconnection provided by National Grid. An automated transfer during outages will be coordinated with National Grid.

As part of the microgrid, the following will be installed:

- **PV (50 kW):** A rooftop PV system will span one side of the south building of the Courthouse Complex.
- **PV (50 kW):** A covered parking PV system will be installed north of the Public Safety Building.
- **CHP (165 kW):** 2 CHP units (130 kW & 35 kW) will be placed inside the south building of the Courthouse Complex.
- **ESS (30 kWh):** An ESS unit will be placed inside the north building of the Courthouse Complex.
- **ESS (10 kWh):** An ESS unit will be placed inside the Public Safety Building.

Modeling Methodology

The microgrid was modeled with HOMER Pro software. HOMER Pro is a microgrid software tool originally developed at the NREL and enhanced and distributed by HOMER Energy. HOMER nests three integrated tools in one software product, allowing microgrid design and economics to be evaluated concurrently. The key features of HOMER Pro are:

- **Simulation:**
  HOMER simulates the operation of a hybrid microgrid for an entire year, in time steps from one minute to one hour.
- **Optimization:**
  HOMER examines all possible combinations of system types in a single run, and then sorts the systems according to the optimization variable of choice.
- **Sensitivity Analysis:**
  HOMER allows the user to run models using hypothetical scenarios. The user cannot control all aspects of a system and cannot know the importance of a particular variable or option without running hundreds or thousands of simulations and comparing the results. HOMER makes it easy to compare thousands of possibilities in a single run.

Load Description

The microgrid design team modeled and optimized each of the eight nodes separately. Table 7 presents an overview of the annual energy operations of the microgrid by node. The microgrid will have a maximum demand of 3,756 kW and an average demand of 1,480 kW. The microgrid will deliver approximately 13,000,000 kWh per year. The thermal loads in the microgrid will be approximately 119,100,000 kBTU per year, of which approximately 29,700,000 kBTU will be recovered from the CHP systems and reused to support on-site thermal loads.

Table 7 –Microgrid Energy Overview: Grid Connected Operation

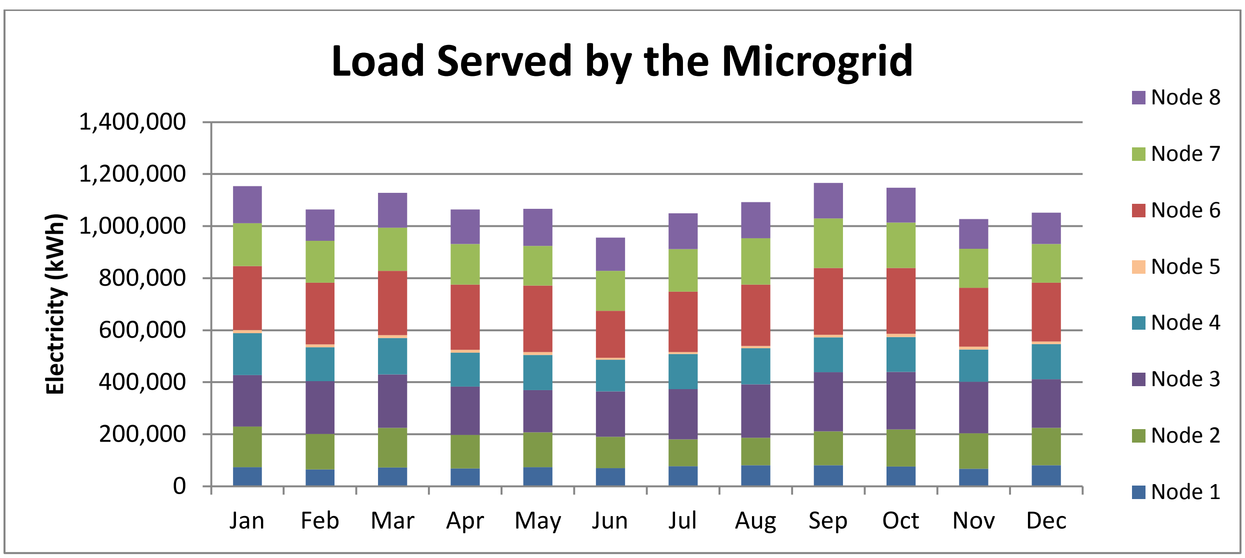
	Electric Demand		Electric Consumption		Thermal Load		Thermal Recovery	
Node	Max (kW)	Avg (kW)	kWh/year	kWh/month	kBTU/year	kBTU/month	kBTU/year	kBTU/month
1	316	101	887,645	73,970	4,976,309	414,692	1,732,884	144,407
2	376	181	1,588,932	132,411	23,284,908	1,940,409	4,259,608	354,967
3	542	269	2,360,340	196,695	20,798,676	1,733,223	5,776,180	481,348
4	599	185	1,617,373	134,781	10,638,819	886,568	4,973,634	414,469
5	85	14	125,775	10,481	1,055,745	87,979	114,177	9,515
6	687	325	2,845,768	237,147	27,227,686	2,268,974	6,001,131	500,094
7	509	224	1,960,494	163,375	21,837,282	1,819,774	3,500,983	291,749
8	642	180	1,580,352	131,696	9,286,639	773,887	3,387,756	282,313
Total	**3,756**	**1,480**	**12,966,681**	**1,080,557**	**119,106,064**	**9,925,505**	**29,746,353**	**2,478,863**

The monthly energy delivery by microgrid node is presented in Table 8 and presented graphically in Figure 6.

Table 8 –Monthly Grid Connected Operation by Node

Month	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Total
	(kWh)								
Jan	73,352	156,600	197,067	161,323	12,673	245,778	164,159	143,250	1,154,202
Feb	65,567	136,530	202,697	129,766	10,556	237,822	161,086	120,594	1,064,619
Mar	72,105	152,475	205,403	139,788	11,330	247,367	165,859	133,213	1,127,541
Apr	68,530	128,748	185,947	130,119	11,852	249,658	157,108	131,582	1,063,544
May	73,956	133,659	162,801	134,573	10,514	255,602	153,226	142,651	1,066,983
Jun	69,685	120,580	174,318	121,531	8,381	180,023	153,419	128,237	956,173
Jul	77,893	102,320	193,298	134,897	8,140	232,000	162,966	137,334	1,048,848
Aug	80,914	105,822	205,088	138,480	8,633	235,856	179,014	138,373	1,092,179
Sep	81,041	129,965	228,094	133,028	10,626	256,088	190,774	136,110	1,165,727
Oct	75,583	142,808	221,360	134,433	12,302	253,029	174,606	133,247	1,147,368
Nov	68,074	135,846	197,732	123,722	11,071	226,364	149,603	115,148	1,027,558
Dec	80,946	143,579	186,534	135,714	9,697	226,180	148,674	120,614	1,051,939
Total	**887,645**	**1,588,932**	**2,360,340**	**1,617,373**	**125,775**	**2,845,768**	**1,960,494**	**1,580,352**	**12,966,681**

Figure 6 - Monthly Grid Connected Operation by Node



The Canton microgrid is designed for a majority of the energy supply to be provided from on-site resources, with the remainder of the energy coming from the grid when the grid is operating. The microgrid treats the utility grid as a key resource and incorporates its characteristics into the microgrid optimization.

The reliability of the Canton Community Microgrid will be ensured with the following measures:

- The use of multiple, distributed, smaller unit sizes to help minimize generation loss and ensure that the microgrid can gracefully accommodate the failure
- The use of distributed energy storage systems that can accommodate short periods of high loading if the resource loss reason is known and quickly recoverable (15 minutes)
- Increasing the energy dispatch from the grid (in grid-connected mode - 99% of the time), to accommodate the loss of a resource until recovered
- The use of a combination of ESS and load modulation (up to 20% without curtailment) in island mode to accommodate the loss of a resource for a few hours. Beyond a few hours, non-critical loads will be shut down until the resource is recovered
- Much greater use of underground cabling and indoor infrastructure than is seen in the traditional utility grid

These techniques are employed in the Canton Community Microgrid design so that equipment loss is mitigated or accommodated in the specific microgrid nodes for this community, under grid-connected and islanded modes of operation. Table 9 summarizes the microgrid resources in each node in terms of number of devices and the total installed capacity by technology.

Table 9 - Microgrid Node Resources Comparison

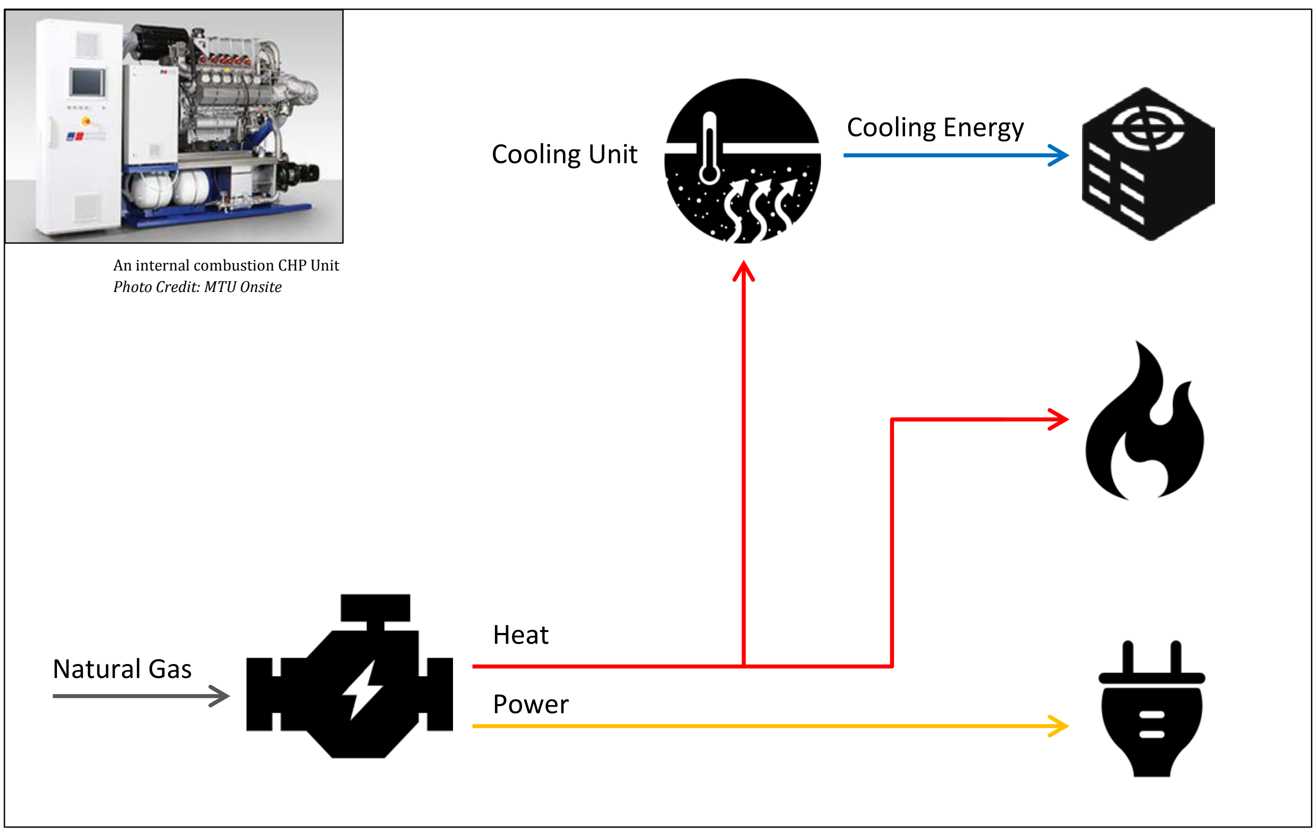
Node	Operation Scenario	Grid	PV		Battery Energy Storage		Natural Gas Engine or CHP		Backup Generators	
		Peak kW	# of Inverters	kW	Qty	kW / kWh	Qty	kW	Qty	kW
1	Business as Usual	316	-	-	-	-	-	-	-	-
	Microgrid	160	1	60	1	25/50	3	105	-	-
2	Business as Usual	376	-	-	-		-	-	-	-
	Microgrid	170	1	220	1	35/70	2	140	-	-
3	Business as Usual	542	-	-	-		-	-	2	2,000
	Microgrid	230	1	360	1	60/120	3	170	2	2,000
4	Business as Usual	599	-	-	-		-	-	1	405
	Microgrid	360	1	90	1	25/50	3	175	1	405
5	Business as Usual	85	-	-	-		-	-	1	60
	Microgrid	57	1	40	1	15/30	1	5	1	60
6	Business as Usual	687	-	-	-		-	-	3	430
	Microgrid	240	2	380	2	130/260	4	235	3	430
7	Business as Usual	509	-	-	-		-	-	1	19
	Microgrid	230	1	380	1	100/200	1	130	1	19
8	Business as Usual	642	-	-	-		-	-	2	355
	Microgrid	467	2	100	2	20/40	2	165	2	355

An overview of each technology, installation, operating strategy, and modeled operation are presented in this section.

Combined Heat and Power

CHP generators provide electrical and thermal energy from a single source. The use of fuel to generate both heat and power makes CHP systems more cost effective than traditional power generation. Most power generation produces heat as a byproduct, but because power is generated far from the end user, the heat is lost. CHP units take advantage of the fact that they are collocated with the end user and make use of thermal energy for heating and sometimes even cooling nearby buildings. For this microgrid application, internal combustion engine based CHP systems have been modeled. Internal combustion engines, also called reciprocating engines, use a reciprocating motion to move pistons inside cylinders that turn a shaft and produce power. Internal combustion engines typically range between 5 kW-7 MW and are best suited for load-following applications. An image of an internal combustion engine generator is presented in Figure 7.

Figure 7 – CHP System Overview



An internal combustion CHP Unit
Photo Credit: MTU Onsite

Benefits of CHP

- Reduces utility costs and improves economic competitiveness
- Increases power reliability and self-sufficiency
- Reduces GHG emissions and other pollutants
- Reduces demand for imported energy supplies
- Capable of operating on renewable or nonrenewable resources
- Suite of proven, commercially available technologies for various applications
- Additional financial incentives through the NYSERDA and investment tax credits available for eligible customers

CHP Approach

- Co-Locate generators near thermal loads on the customer-side of the meter
- Design for base load operation and to maximize heat recovery
- Support microgrid operations when the electric grid is not available along with PV, energy storage, and building load control
- Design to serve specific winter Heat Recovery Loads, such as a boiler plant, space heating, DHW, and pool heating
- Design to serve specific summer Heat Recovery Loads, including space cooling, DHW, and pool heating

CHP in the Microgrid

The size and location of the planned CHP units is presented in the layout diagram and single-line diagram presented in the Appendix. Table 10 summarizes the CHP components by node of the microgrid.

Table 10 - Microgrid CHP Resources by Node

Node	Natural Gas Engine or CHP	
	Quantity	Total kW
1	3	105
2	2	140
3	3	170
4	3	175
5	1	5
6	4	235
7	1	130
8	2	165
Total	**19**	**1,125**

The following tables and figures summarize the annual operation of the CHP fleet in the Canton microgrid on a monthly basis for each node.

Table 11 - Microgrid CHP Electric Production by Node

Month	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Total
	Electric Production (kWh)								
Jan	54,156	101,011	124,231	92,878	3,179	169,749	89,498	99,782	734,485
Feb	49,716	90,259	112,546	76,431	2,819	152,001	80,564	85,246	649,582
Mar	53,132	96,949	120,872	79,965	2,884	166,116	85,032	84,666	689,617
Apr	51,453	92,375	120,375	73,503	3,002	166,439	82,404	79,563	669,114
May	56,468	93,499	123,423	77,270	2,924	174,219	84,532	82,017	694,353
Jun	49,983	86,594	118,057	71,094	2,461	162,503	86,914	73,307	650,912
Jul	52,606	83,802	125,416	74,411	2,586	172,716	88,683	77,763	677,983
Aug	53,278	85,162	125,433	76,116	2,681	173,381	93,200	75,303	684,554
Sep	54,839	89,908	118,987	75,072	2,975	165,888	87,925	79,887	675,480
Oct	53,567	98,206	125,303	77,609	3,213	173,328	91,769	78,685	701,679
Nov	53,338	94,897	120,941	71,288	3,042	165,221	86,948	74,159	669,834
Dec	59,080	97,205	121,581	79,729	3,022	169,755	85,350	81,123	696,844
Total	**641,617**	**1,109,867**	**1,457,165**	**925,365**	**34,787**	**2,011,315**	**1,042,820**	**971,502**	**8,194,439**

Figure 8 – Microgrid CHP Electric Production

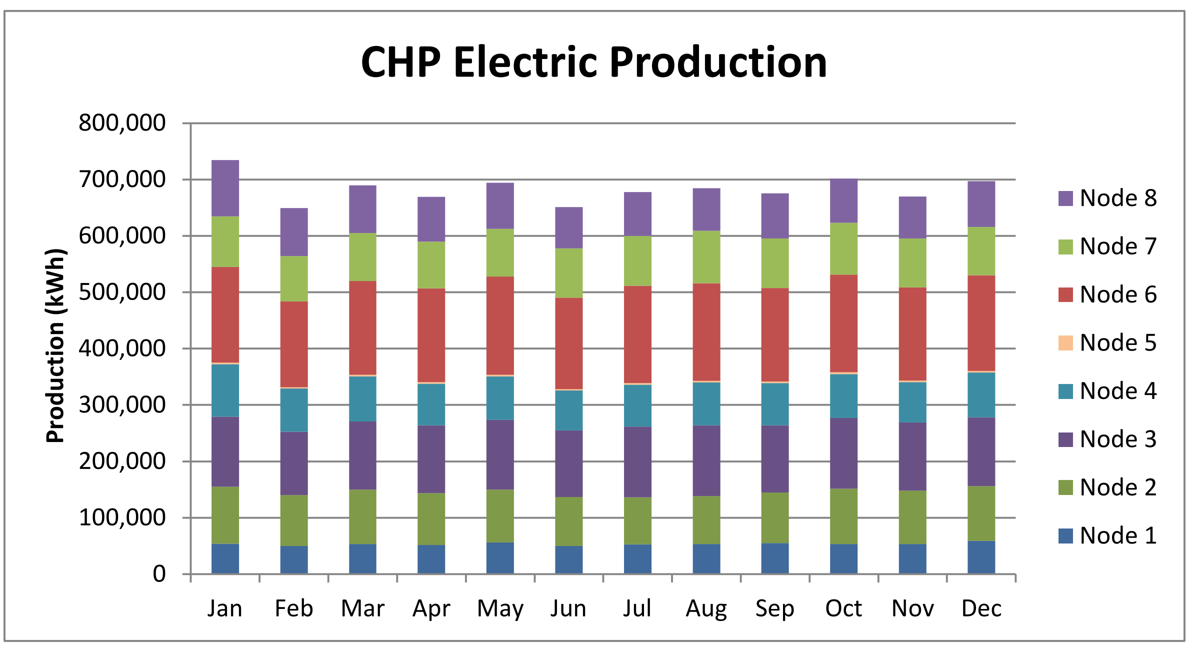


Table 12 - Microgrid CHP Heat Recovery by Node

Month	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Total
	Heat Recovery (kBTU)								
Jan	192,643	489,780	576,232	514,934	14,081	732,523	440,479	476,542	3,437,214
Feb	176,849	438,513	520,520	430,871	12,484	655,625	396,601	405,913	3,037,374
Mar	188,999	470,951	559,939	456,753	12,774	715,996	418,621	392,359	3,216,392
Apr	182,985	448,842	550,040	423,240	13,295	710,415	403,408	365,528	3,097,753
May	166,337	374,716	496,351	443,500	8,893	610,469	292,547	279,409	2,672,222
Jun	44,384	145,295	298,817	321,123	4,038	236	22,908	87,943	924,742
Jul	21,522	124,805	272,216	402,420	3,736	0	2	94,468	919,169
Aug	15,975	104,759	384,784	266,682	3,530	0	3,932	93,481	873,143
Sep	153,140	291,657	462,783	418,194	3,023	418,003	243,968	155,487	2,146,255
Oct	190,428	439,736	549,611	428,038	14,065	720,880	433,079	330,952	3,106,789
Nov	189,467	457,914	541,604	412,290	10,883	706,400	425,243	333,344	3,077,145
Dec	210,156	472,642	563,284	455,588	13,376	730,585	420,196	372,329	3,238,157
Total	**1,732,884**	**4,259,608**	**5,776,180**	**4,973,634**	**114,177**	**6,001,131**	**3,500,983**	**3,387,756**	**29,746,353**

Figure 9 – Microgrid CHP Heat Recovery

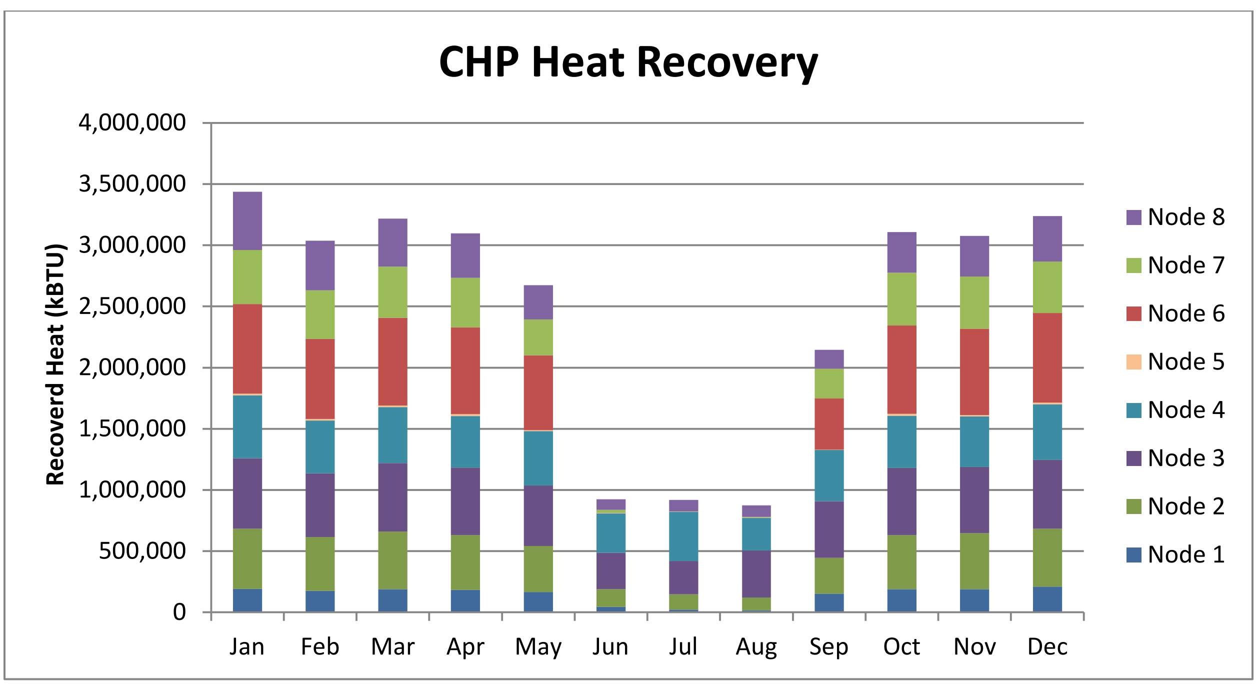
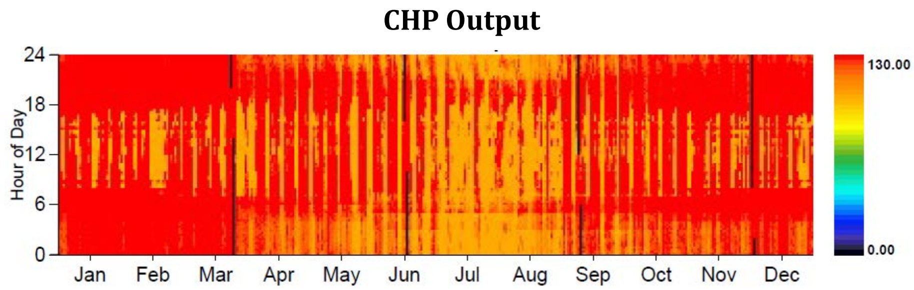


Figure 10 presents the hourly operation of the CHP in Node 2 in the form of a heat map. This representation demonstrates that the CHP unit is operating near full capacity for a majority of hours (red), then does some electric load following during the other hours (orange) but is loaded at an overall high level of output during the course of the year.

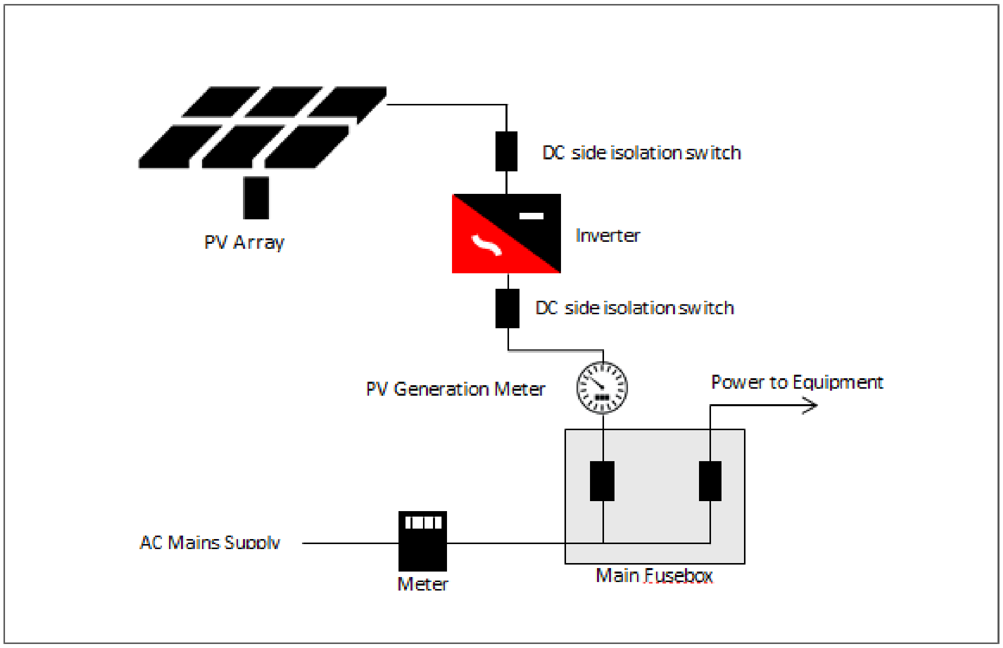
Figure 10 – Node #2 CHP Operational Summary



Solar Photovoltaics

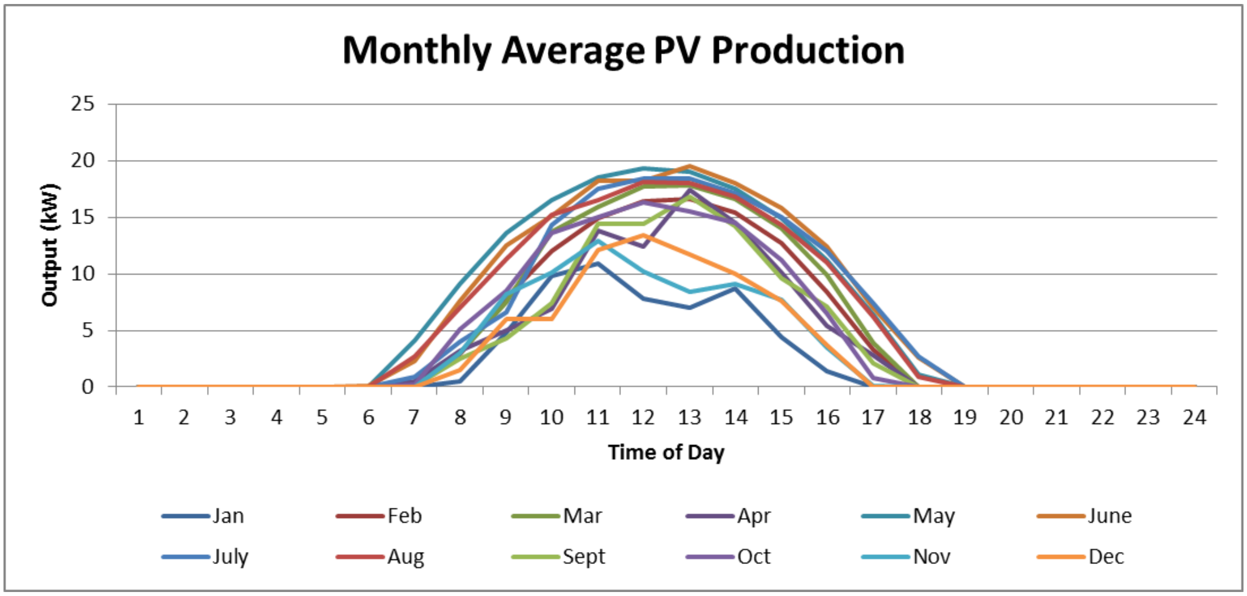
The PV systems will be rooftop, parking lot, or ground mounted using hail-rated solar panels. PV devices generate electricity directly from sunlight via an electronic process that occurs naturally in certain types of material, called semiconductors. Electrons in these materials are freed by photons and can be induced to travel through an electrical circuit, resulting in the flow of electrons to create energy in the form of direct current. The direct current is transformed into usable alternating current through the use of an inverter. A typical customer-side of the meter PV installation is presented in Figure 11.

Figure 11 – PV Installation Diagram (Customer Side of Meter)



Since the PV systems are driven by sunlight, the electric production profile varies with the position of the sun and is impacted by the level of cloud cover. Figure 12 presents the typical average daily PV generation profiles by month and demonstrates the seasonal variation of PV as a generation resource. The HOMER model takes this variability into account when simulating and optimizing the sizing of PV as a microgrid resource.

Figure 12 – Typical PV Daily Generation Profiles



PV systems are planned for rooftops, parking spaces, and ground-mount configurations. Figure 13 presents examples of each these types of installations

Figure 13 – PV Installation Options.

Benefits of PV

- Reduces utility costs and improves economic competitiveness
- Increases power reliability and self-sufficiency
- Reduces GHG emissions and other pollutants
- Reduces demand for imported energy supplies
- Fueled by a renewable resource
- Based on a suite of proven, commercially available technologies for a variety of applications
- Competitive market for hardware and installation services

PV Approach

- Co-locate PV systems on the customer-side of the meter to support resiliency
- Install on roofs, ground mount and covered parking
- Provide renewable energy resource (reduce site emissions and no fuel cost)
- Support day-time load requirements and annual energy loads (grid connected operation)
- Support microgrid operations when the electric grid is not available along with CHP, energy storage, and building load control

PV in the Microgrid

The size and locations of the planned PV systems is presented in the layout diagram and single-line diagram in the Appendix. Table 13 summarizes the PV components by node of the microgrid.

Table 13 - Microgrid PV Resources by Node

Node	PV	
	# of Inverters	Total kW
1	1	60
2	1	220
3	1	360
4	1	90
5	1	40
6	2	380
7	1	380
8	2	100
Total	**10**	**1,630**

The below table and figures below describe the PV fleet.

Table 14 – Microgrid PV Fleet Electric Production

Month	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Total
Electric Production (kWh)									
Jan	6,374	22,894	37,462	9,560	4,249	39,543	39,543	10,623	170,249
Feb	6,738	24,303	39,769	10,107	4,492	41,978	41,978	11,230	180,595
Mar	8,743	31,622	51,745	13,114	5,829	54,620	54,620	14,571	234,863
Apr	7,616	27,759	45,424	11,423	5,077	47,947	47,947	12,693	205,885
May	7,867	28,705	46,972	11,801	5,245	49,582	49,582	13,112	212,868
Jun	7,496	27,334	44,728	11,245	4,998	47,213	47,213	12,494	202,719
Jul	7,308	26,653	43,615	10,962	4,872	46,038	46,038	12,180	197,664
Aug	7,383	26,895	44,011	11,074	4,922	46,456	46,456	12,304	199,499
Sep	7,573	27,555	45,090	11,360	5,049	47,595	47,595	12,622	204,441
Oct	7,320	26,698	43,688	10,980	4,880	46,116	46,116	12,200	197,997
Nov	5,915	21,195	34,683	8,872	3,943	36,610	36,610	9,858	157,687
Dec	6,056	21,669	35,458	9,083	4,037	37,428	37,428	10,093	161,251
Total	**86,448**	**313,283**	**512,645**	**129,581**	**57,592**	**541,125**	**541,125**	**143,979**	**2,325,777**

Figure 14 – Microgrid PV Fleet Electric Production

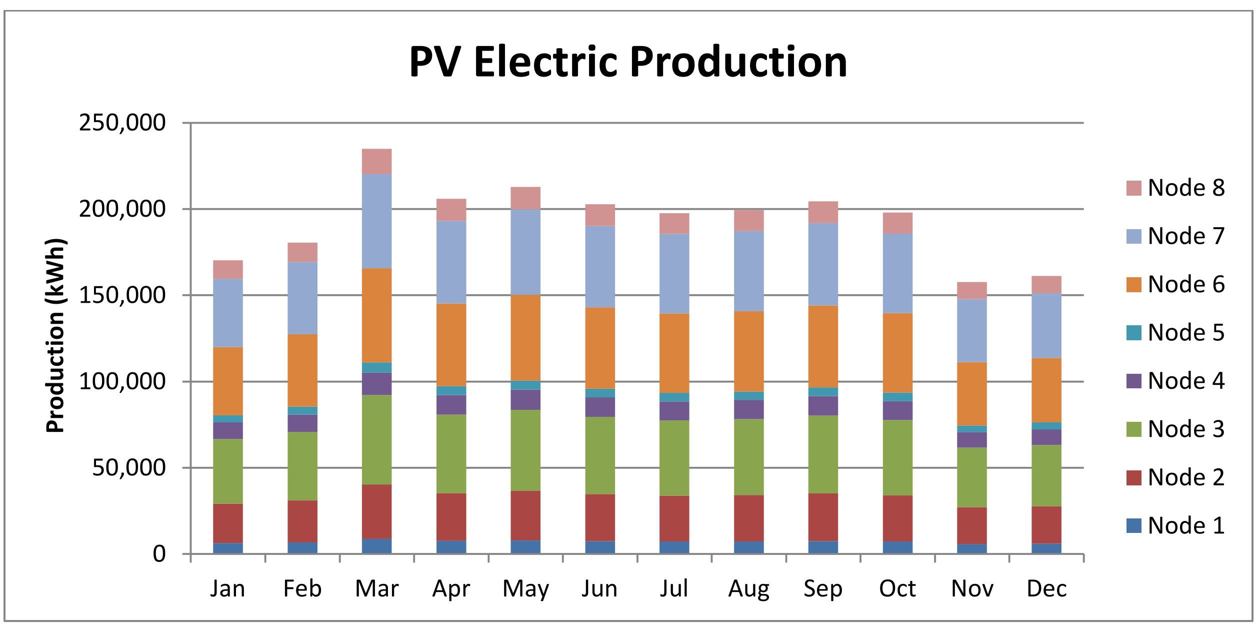
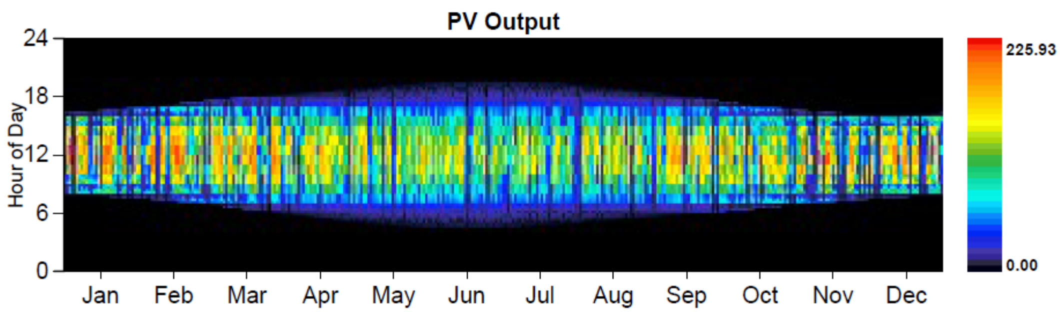


Figure 15 presents the hourly operation of the PV in Node 2 in the form of a heat map. This representation demonstrates how the PV units operate during hours of sunshine with maximum production in the middle of the day, ramping up in the mornings and ramping down in the afternoon hours. This also illustrates the trend of narrower daily bands of production in the winter and then expansion to maximum production in the summer.

Figure 15 – Node #2 PV Operational Summary



Energy Storage Systems

Energy storage in a microgrid can improve the payback period for the whole system by enabling an increase in the penetration of renewable energy sources, shifting the energy produced by PV, enabling peak load management, managing PV intermittency, providing volt/VAr support, and supporting island mode transitions. The technology specified for the Canton microgrid is Lithium Ion (Li-ion) batteries, which have a fast reaction response to changes in load, a fairly small footprint, and a relatively high round trip efficiency. Li-ion batteries have some unique operational characteristics:

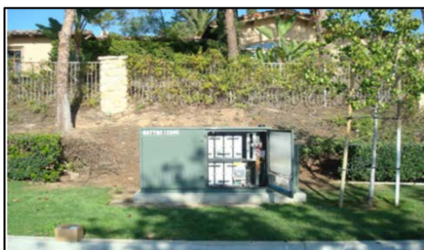
- The usable energy capacity is between a 15% and 95% state of charge (SOC)
- The life of the batteries are impacted by temperature and charge rate
- Most systems are capable of approximately 3,000 deep discharge cycles (+/- 80% SOC cycles)
- Most systems are capable of more than 100,000 shallow discharge cycles (+/- 15% SOC cycles)
- The batteries are at a high risk of failure if the system is discharged to a zero percent sate of charge
- The systems typically have different rates (kW) for charge and discharge
- Most Li-ion systems have accurate methods of determining the system SOC
- Typical power electronic systems provide multiple modes of operation
- Systems are typically capable of four quadrant operation

Benefits of Energy Storage

- Reduces utility costs and improves economic competitiveness
- Increases power reliability and self-sufficiency
- Reduces GHG emissions and other pollutants
- Reduces demand for imported energy supplies
- Supports system with a high level of renewable energy penetration
- Based on a suite of proven, commercially available technologies for a variety of applications
- Competitive market for hardware and installation services
- Provides multiple functions and benefits to the microgrid:
  - Peak Load Management
  - Load Shifting
  - Frequency Regulation
  - Reactive Power Support
  - PV Support
  - Demand Response
  - Energy Arbitrage
  - Backup Power

Figure 16 presents examples of energy storage installations for the technologies addressed for this microgrid design.

Figure 16 – Example ESS Installations



25 kW / 75 kWh pad mount system

25 kW / 50 kWh pad mount system with storage in underground vault

Multiple 5 kW / 12 kWh systems

Energy Storage Approach

- Co-Locate with PV systems on the customer-side of the meter to support resiliency
- Install indoors or outdoors (indoor installation better for resiliency)
- Maximize functional benefits for the microgrid
- Support microgrid operations when the electric grid is not available along with CHP, energy storage, and building load control

ESS in the Microgrid

The size and location of the planned ESS systems is presented in the layout diagram and single-line diagram presented in the Appendix. Table 15 summarizes the ESS components by node of the microgrid.

Table 15 - Microgrid ESS Resources by Node

Node	Battery Energy Storage		
	Quantity	kW	kWh
1	1	25	50
2	1	35	70
3	1	60	120
4	1	25	50
5	1	15	30
6	2	130	260
7	1	100	200
8	2	20	40
Total	**10**	**410**	**820**

Unlike the other microgrid resources, the ESS both consumes and produces energy. When properly used, the net energy consumed is very small. The annual operation of the ESS in Node 2 is presented in Table 16, which shows both the charge and discharge modes of operation. The net value is positive which takes into account the operational losses for the systems.

Table 16 – Microgrid ESS Operation Sample Node

Month	Charge	Discharge	Net
		(kWh)	
Jan	2,343	2,156	187
Feb	2,642	2,431	211
Mar	2,913	2,452	461
Apr	2,341	2,382	-41
May	2,614	2,405	209
Jun	2,550	2,168	382
Jul	3,614	3,447	168
Aug	4,062	3,702	360
Sep	1,860	1,752	108
Oct	2,337	2,201	137
Nov	2,605	2,397	208
Dec	2,888	2,657	231
Total	**32,770**	**30,148**	**2,622**

Figure 17 – Microgrid ESS Operation

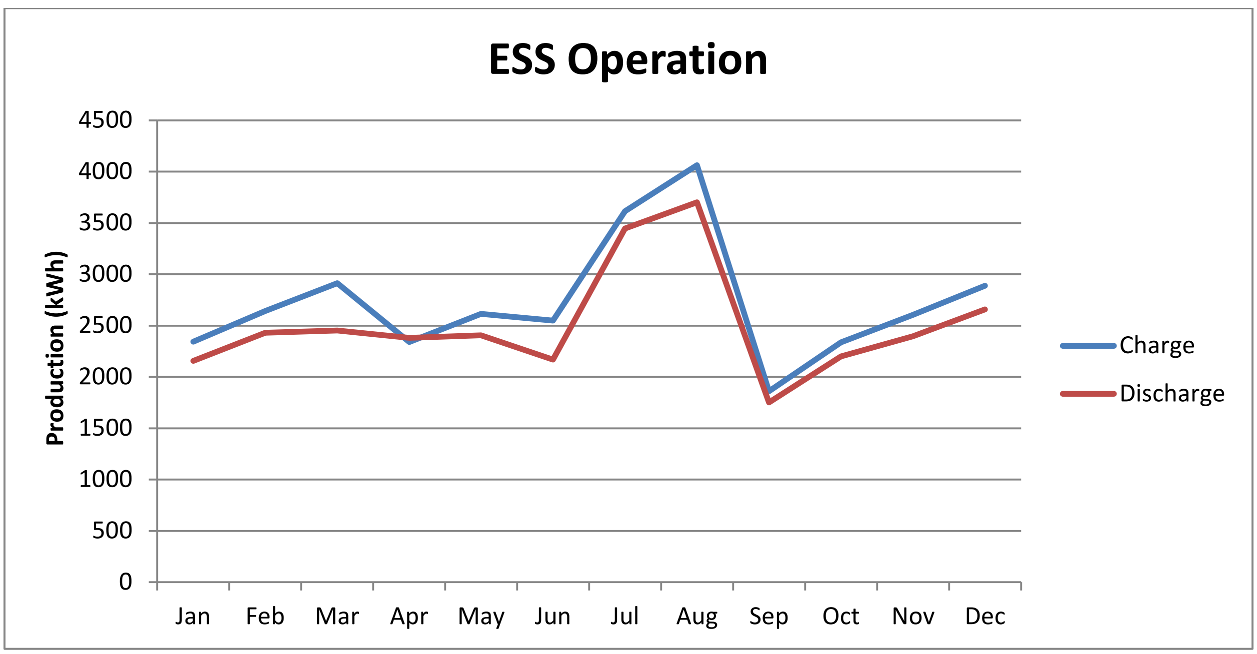
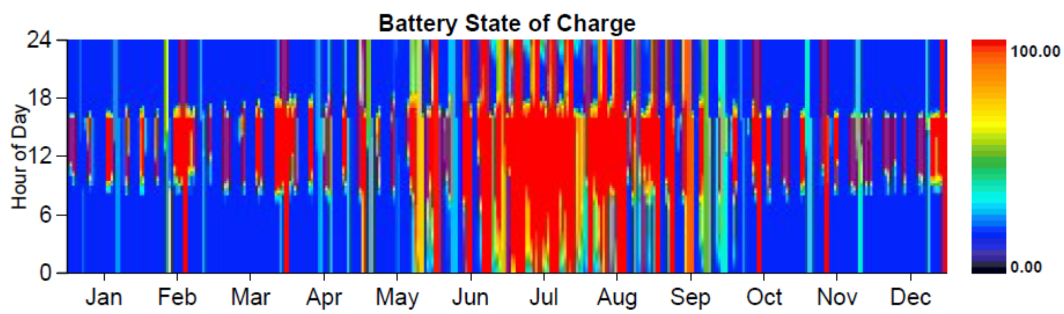


Figure 18 presents the hourly operation of the ESS in node 2 in the form of a heat map. This representation demonstrates how the ESS units operate. Typically, the units are charged to a high SOC in the middle of the day. The operations represent PV intermittency support, PV load shifting, peak shaving (to manage utility imports), and supporting CHP loading.

Figure 18 – Node #2 ESS Operational Summary



Island Mode Modeling Results

The resources included in the Canton Community Microgrid have been sized and operated to support island operation for a minimum period of seven days, with multi-week operation likely. During island mode operation, the microgrid control system will maintain system stability and ensure a balance of generation and load. The controller will forecast critical load and PV generation and then dispatch resources to match the load. We anticipate that the resources available to be controlled during island operations will include CHP, fossil fuel generators, PV systems, energy storage, and building load. We also expect that the utility will be able to provide an estimated time to restoration. This estimate will be used to help determine the remaining duration of island operation required, and will influence the dispatch of microgrid resources.

The design strategy for the Canton Community Microgrid is to supply the critical load at a level that enables the critical services that keep the community functioning at a sufficient level throughout the entire event duration. This provides full functionality for police, fire, and emergency services while also providing some level of heat and power to other facilities and residents. Each node was modeled for operation during an extended outage (one week) to evaluate and optimize microgrid resources operating in island mode. Two outage events were modeled to represent an outage during the winter and an outage during the summer. Energy flows during the outages are presented as weekly averages in Table 17.

Table 17 –Microgrid Energy Overview: Island Mode Operation

Node	Season	Electric Demand		Electric Consumption	Thermal Load	Thermal Recovery
		Max (kW)	Avg (kW)	kWh/week	kBTU/week	kBTU/week
1	Winter	199	97	16,348	222,632	53,000
	Summer	190	95	15,969	5,434	5,421
2	Winter	328	191	32,015	1,241,289	125,734
	Summer	235	160	26,819	31,545	31,545
3	Winter	389	332	55,701	982,990	105,797
	Summer	435	307	51,641	69,360	64,803
4	Winter	550	253	42,468	364,211	111,110
	Summer	427	201	33,849	119,907	88,451
5	Winter	71	20	3,348	65,842	655
	Summer	27	12	2,028	1,488	654
6	Winter	483	404	67,874	1,378,327	129,674
	Summer	508	360	60,504	0	0
7	Winter	334	217	36,477	1,125,112	108,965
	Summer	377	219	36,796	0	0
8	Winter	500	225	37,733	491,347	124,603
	Summer	496	201	33,700	23,879	23,879
Total	**Winter**	**2,852**	**1,738**	**291,964**	**5,871,750**	**759,538**
	Summer	**2,696**	**1,555**	**261,307**	**251,612**	**214,753**

FINANCIAL FEASIBILITY

The outputs of the technical modeling process described above were used to evaluate the financial viability of the proposed microgrid from two perspectives. First, the project team analyzed the financial strength of the project using the proposed third-party ownership business model. Under this model, the project is funded through outside investment and debt which is recouped through power purchase agreements with each facility. In addition, NYSERDA contracted with Industrial Economics, Incorporated (IEc) to perform a benefit-cost analysis. The focus of this analysis is to evaluate the societal benefits of the microgrid, including benefits from emissions reductions, cost reductions, and resilience improvements.

Installed Cost

At this feasibility stage of the project, a high-level project budget was developed and incorporated into the sizing model to ensure that the design meets both the technical and economic elements of the project. Cost elements include engineering, permitting, capital equipment, site preparation, construction, controls, start-up, commissioning, and training. Site preparation also includes the addition and modification of electrical infrastructure for undergrounding distribution lines, PCC controls, monitoring, and protection equipment. Some of these infrastructure costs may be paid to the electric utility. The estimated installed cost of the proposed microgrid is approximately $8,380,00 with an accuracy of +/- 25% (within the +/- 30% set by NYSERDA). When the federal investment tax credit is applied, the net installed cost is $6,102,000. This cost does not include incentives that may be applicable to the project. The plan is to take advantage of all applicable incentives for the project.

The project team evaluated several available financial incentives when performing the financial analysis for the Canton Community Microgrid. The following programs[1] were evaluated:

- **Demand Response**: National Grid's demand response programs pay customers who are able to temporarily reduce electric usage when requested. This capability will be improved by the existence of the microgrid.
- **Sales Tax Exemption**: Solar photovoltaic systems are 100% free from state and local taxes.
- **Business Energy Investment Tax Credit (ITC):** The ITC includes a 30% tax credit for solar or fuel cell systems on residential and commercial properties and 10% tax credit for CHP systems. In December, the ITC was extended for three years, with a ramp-down through 2022.
- **NYSERDA PON 2568 CHP Acceleration Program**: This program provides financial incentives for the installation of CHP systems at customer sites that pay the SBC surcharge on their electric bill, and will be fueled by natural gas that is subject to the SBC surcharge on the gas bill.
- **NY SUN initiative:** This program provides rebates and performance incentives for new residential and commercial solar PV installations. The program provides up to $0.34 per watt for new installed PV that displaces existing usage. An additional incentive of $50,000 applies if the project includes energy storage. An additional incentive of $50,000 applies if the project includes integrated energy efficiency. The program will provide up to 50% of the total installed system cost.
- **New York Power Authority – Energy Services Program for Public Utilities**: This program provides various rebates on energy efficient equipment.
- **NYSERDA Sub Metering Program**: This program will provide $250 incentive for each advanced sub meter and $1,500 for each master meter.
- **Federal Energy-Efficient Commercial Buildings Tax Deduction**: This deduction provides $0.30-$1.80 per square foot, depending on technology and amount of energy reduction for buildings that become certified as meeting specific energy reduction targets as a result of improvements in interior lighting; building envelope; or heating, cooling, ventilation, or hot water systems.

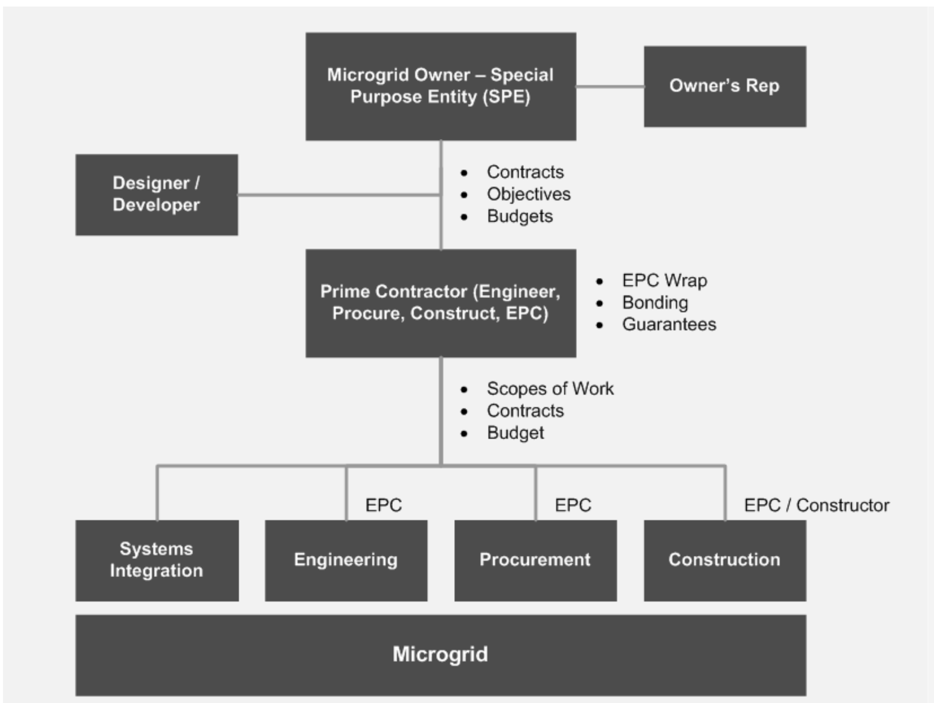
[1] Identified from the DSIRE database as of December 2015. http://programs.dsireusa.org/system/program?state=NY

Third Party Ownership

Under the proposed business model, a third party would fund all development and construction of the microgrid, own and operate the assets, and sell the energy generated from the microgrid to community customers through PPAs.

The SPE will engage the design team to finalize the construction drawings and utility interconnection agreements. The SPE will engage an engineering, procurement, and construction firm to build the microgrid, and will be financially responsible for all engineering, procurement, and construction for the system. The SPE will also be financially responsible for integrating the controls and communications systems. This process is presented in the Figure 19.

Figure 19: Microgrid Development Relationships



To ensure proper operation of individual microgrid resources, an energy performance contractor (selected through a partnership or solicitation, and hired by the SPE) will conduct site acceptance tests that validate the operation and performance of the new equipment. Once the system construction and integration are complete, the SPE will engage a third party commissioning agent that will test the microgrid as a system to ensure that the controls, communication and sequence of operation function to meet the requirements as defined in the specified use cases and the final design. After the fully commissioned system is accepted and transferred to the SPE, the SPE will own and operate the microgrid for a period of 25 years. If selected for Stage 2, the team would evaluate how shorter PPA periods would affect the cost of electricity and discuss those options with the microgrid system participants.

The operation of the microgrid will leverage the autonomous functionality of the microgrid controller, and minimize the need for on site operators. The controller will operate the microgrid to maximize economic benefits, minimize emissions, and maximize reliability of service in the event of a fault on the grid. In addition, the microgrid controller will monitor the performance, operation and alarms of the distributed resources. In the event of an alarm, the SPE will be notified through the network operations center, and dispatch a service technician who will be engaged through a service contract. The microgrid controller will also track the hours of operation of each microgrid resource, and will employ a predictive maintenance strategy to schedule maintenance before any failure occurs, and at a time that will have the least impact on the overall operation of the microgrid. As the microgrid operates, a history of performance, trending and signature analyses will develop, adding to the microgrid's ability to anticipate failures.

The project team conducted a thorough econometric analysis of the proposed Canton Community Microgrid to determine the financial viability of the project. Hitachi has developed proprietary economic modelling software, known as EconoSCOPE™, which is specifically designed to support financial analysis for public infrastructure projects. The project team used this software to support the analysis of the financial viability of the Canton Community Microgrid project. Financial institutions do not yet allow for recognition of incentives in their evaluations of project attractiveness. Therefore, the project team did not include them in the underlying economic analysis at this time. During the detailed design phase, financial incentives will be evaluated as part of the entire system costs.

The current weighted electric rate of the key critical facilities included in the proposed microgrid is approximately $0.089/kWh. This low cost is primarily driven by the two universities who have negotiated attractive commodity prices for their electric supply. Based on the third party ownership business model, assumed project financing costs, and the 25 year contract term, the model indicates a PPA electric rate above the current rates for the facilities in this project.

Cost Benefit Analysis

NYSERDA contracted with IEc to conduct a benefit-cost analysis. The project team provided detailed information to IEc to support this analysis. IEc ran two scenarios for this proposed microgrid. The first scenario modeled no power outages, and evaluated the grid connected mode of operation. The second scenario modeled the number of days (or partial days) of outage at which the costs of the microgrid would be equal to its various benefits, thus yielding a cost benefit ratio of 1. For the Canton Community Microgrid, the breakeven outage case is one outage per year for a duration of half a day. The cost benefit results are presented in Table 18. The analyses indicate that if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to equal or exceed 0.5 days per year (Scenario 2).

Table 18 – Cost Benefit Analysis Summary Results

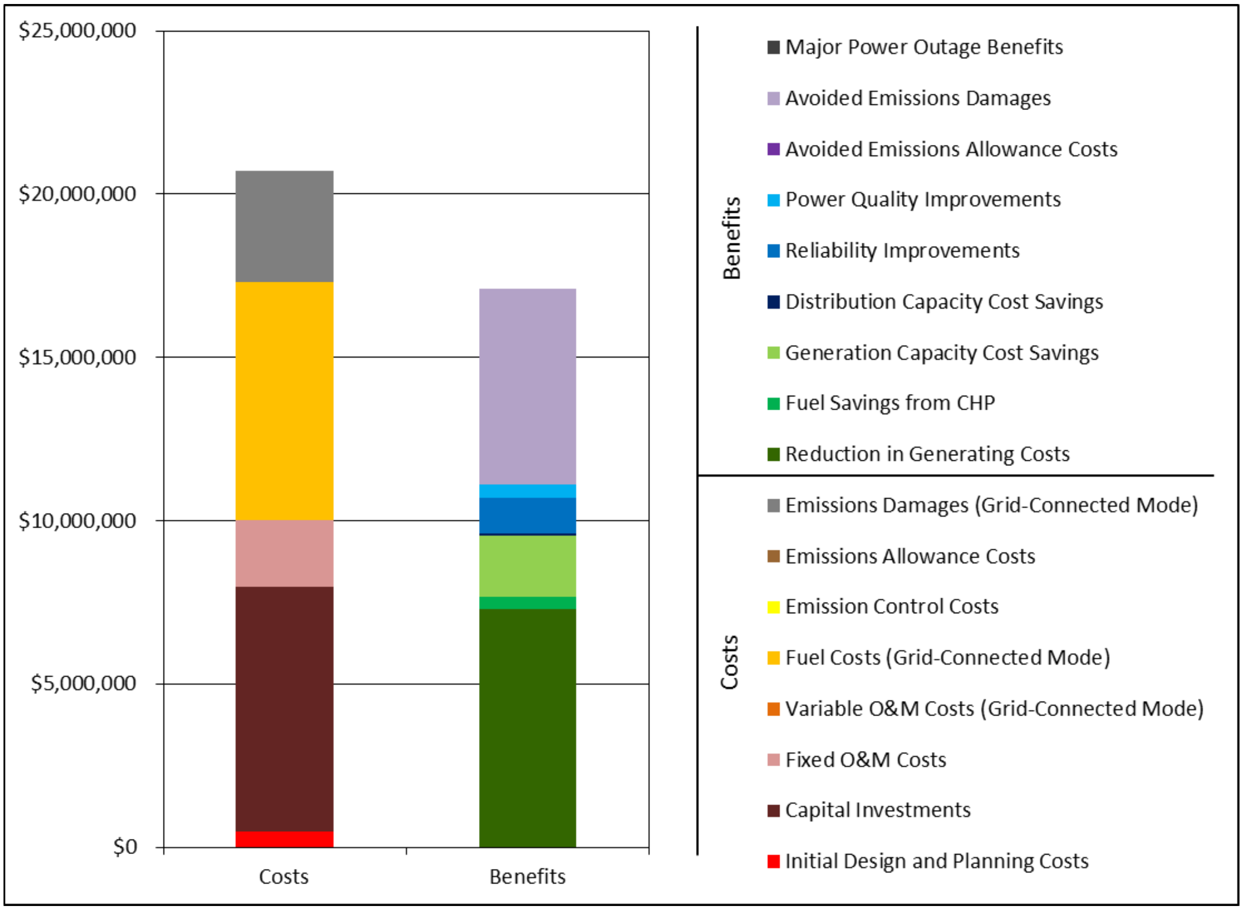
Economic Measure	Assumed average duration of major power outages	
	Scenario 1: 0 DAYS/YEAR	Scenario 2: 0.5 DAYS/YEAR
Net Benefits - Present Value	-$3,610,000	$424,000
Total Costs – Present Value	$20,700,000	$20,700,000
Benefit-Cost Ratio	0.8	1.0
Internal Rate of Return	-0.6%	6.5%

The cost benefit analysis results for scenario 1 are presented in Table 19. The results indicate that if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to equal or exceed 0.5 days per year (Scenario 2).

Table 19 – Cost Benefit Analysis Scenario 1
(No Major Power Outages; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value over 20 Years (2014$)	Annualized Value (2014$)
Costs		
Initial Design and Planning	$475,000	$41,900
Capital Investments	$7,500,000	$598,000
Fixed O&M	$2,040,000	$180,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$7,300,000	$644,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$3,390,000	$222,000
Total Costs	**$20,700,000**	
Benefits		
Reduction in Generating Costs	$7,300,000	$644,000
Fuel Savings from CHP	$357,000	$31,500
Generation Capacity Cost Savings	$1,880,000	$166,000
Distribution Capacity Cost Savings	$67,300	$5,940
Reliability Improvements	$1,080,000	$95,400
Power Quality Improvements	$426,000	$37,600
Avoided Emissions Allowance Costs	$3,820	$337
Avoided Emissions Damages	$5,980,000	$390,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$17,100,000**	
Net Benefits	**-$3,610,000**	
Benefit/Cost Ratio	**0.8**	
Internal Rate of Return	**-0.6%**	

Figure 20 – Cost Benefit Analysis Scenario 1
(No Major Power Outages; 7 Percent Discount Rate)

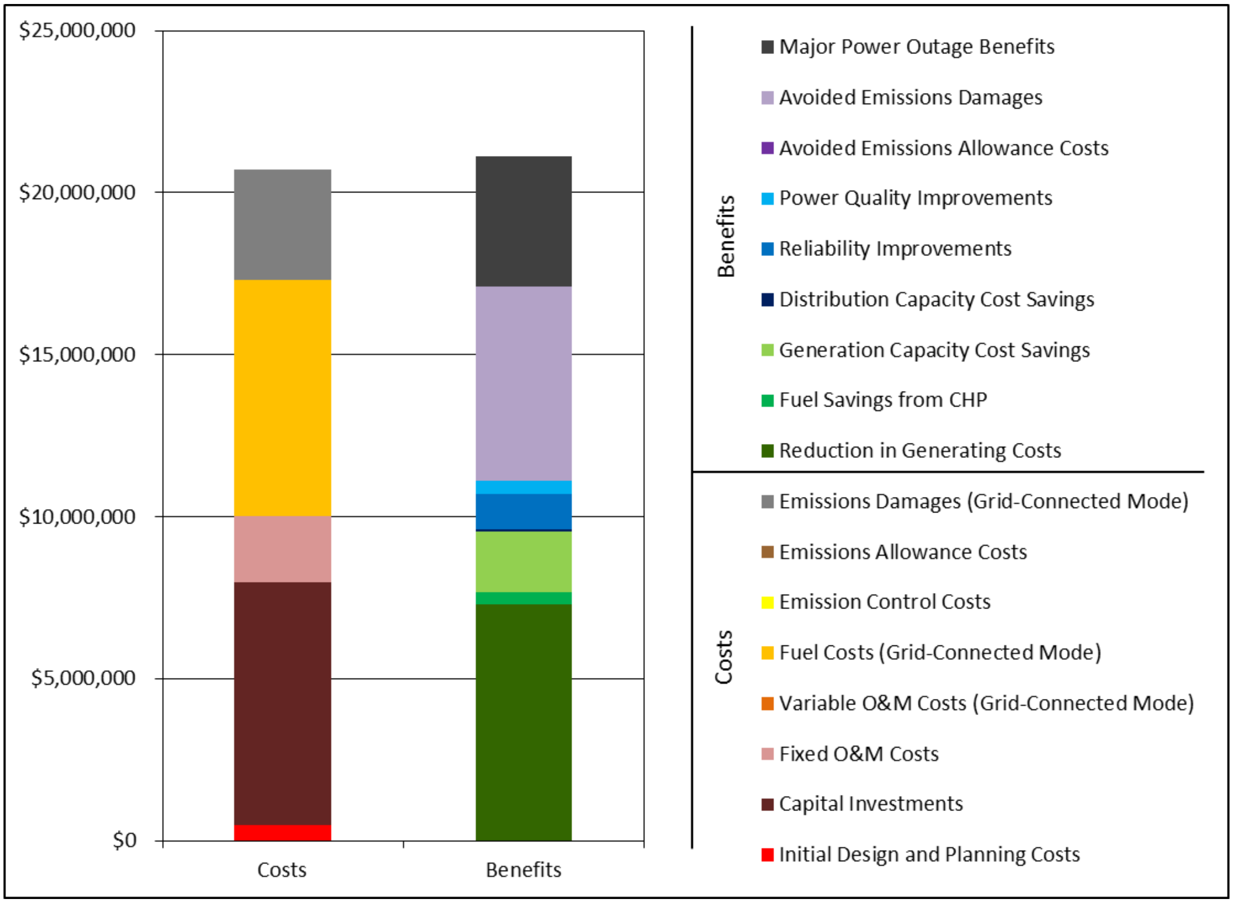


The major drivers of costs are the capital investments and fuel, where the major benefits are reduction in generation costs and avoided emissions damages.

Table 20 – Cost Benefit Analysis Scenario 2
(Major Power Outages Averaging 0.5 Days/Year; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value over 20 Years (2014$)	Annualized Value (2014$)
Costs		
Initial Design and Planning	$475,000	$41,900
Capital Investments	$7,500,000	$598,000
Fixed O&M	$2,040,000	$180,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$7,300,000	$644,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$3,390,000	$222,000
Total Costs	**$20,700,000**	
Benefits		
Reduction in Generating Costs	$7,300,000	$644,000
Fuel Savings from CHP	$357,000	$31,500
Generation Capacity Cost Savings	$1,880,000	$166,000
Distribution Capacity Cost Savings	$67,300	$5,940
Reliability Improvements	$1,080,000	$95,400
Power Quality Improvements	$426,000	$37,600
Avoided Emissions Allowance Costs	$3,820	$337
Avoided Emissions Damages	$5,980,000	$390,000
Major Power Outage Benefits	$4,040,000	$356,000
Total Benefits	**$21,100,000**	
Net Benefits	**$424,000**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**6.5%**	

Figure 21 – Cost Benefit Analysis Scenario 2
(Major Power Outages Averaging 0.5 Days/Year; 7 Percent Discount Rate)



The benefits from the half day outages result in $4,040,000 during the life of the microgrid. The entirety of the IEC analysis can be found in Appendix D of this report.

Model Comparisons

This benefit-cost analysis differs from the third party ownership financial feasibility analysis performed by the project team in several ways. In addition to the differing objectives of these two analyses, the underlying assumptions used in each also differed. A few of these differences affected the results of these analyses in significant ways, including:

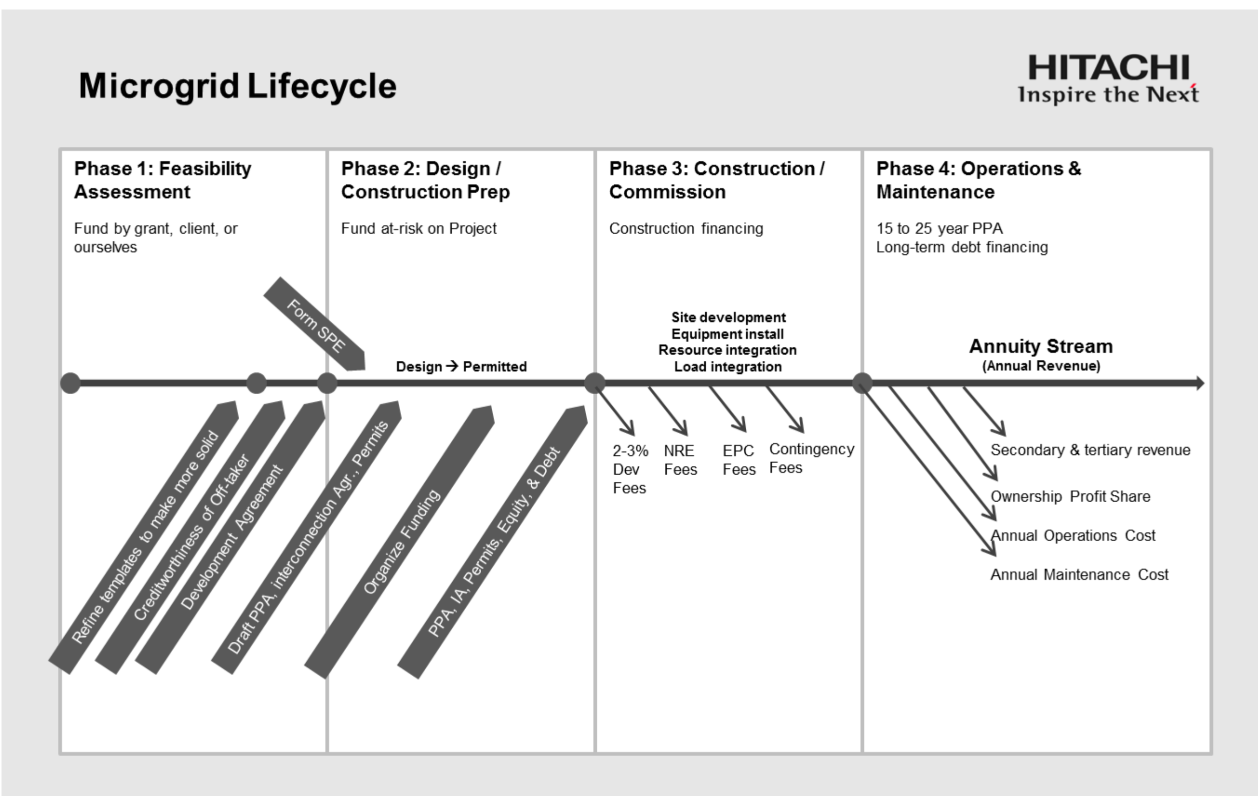
- Gas rates used in IEC's benefit-cost analysis were based on a state-wide average for commercial end-use customers. The rates used in Canton's financial feasibility analysis are based on available rate data from St. Lawrence Gas, and assumptions about likely discounts associated with CHP deployments (based on experience with other New York utilities). This resulted in year 1 gas rates of $6.34 and $3.97, for the benefit-cost analysis and the financial feasibility analysis, respectively. If the estimated distributed generation rate were applied to the benefit-cost analysis, net benefits would be increased by $2.54M.

- The benefit-cost analysis derives a price for electricity based on average wholesale energy costs, whereas the financial feasibility assessment evaluates the savings to the community based on actual costs paid by community participants.
- The financial feasibility assessment incorporates the tax benefits of the Federal Investment Tax Credit, whereas the benefit-cost analysis does not. This benefit reduces the capital cost of the project by $2.27M.
- Capital replacement costs used in the benefit-cost analysis were calculated as a full replacement costs, whereas the project team assumed a 'rebuild' cost that is not equal to the full cost of replacement. If the 'rebuild' costs were applied to the benefit-cost analysis, net benefits would be increased by $142,000.
- The period of analysis in the benefit cost analysis is 20 years and the third party ownership model is based on a period of analysis of 25 years.

Development, Construction, and Operating Approach

Once the design phase of a microgrid project is complete, the project must be brought to life by a well-designed and effectively supported development approach. The Hitachi Microgrid Lifecycle process closely matches the NY Prize process shown in Figure 20:

Figure 22: Hitachi Microgrid Lifecycle



In addition to the elements included in NY Prize Stage 1, the Hitachi Microgrid Lifecycle includes an evaluation of the off-taker creditworthiness.

In addition to the elements included in NY Prize Stage 2, the Hitachi Microgrid Lifecycle includes establishing a SPE early in the process to formulate the business model negotiation.

Prior to construction, it is important to clearly define the manner in which operations and maintenance (O&M) will be managed once the microgrid is operational. There are multiple options for handling microgrid O&M:

- System owner O&M – The system owner, or SPE, hires staff to operate and maintain the microgrid.
- O&M Contractor – The SPE hires an O&M contractor under a long term service-level agreement.
- Separate Operations and Maintenance Contractors – The SPE hires separate operations and maintenance contractors under long term service-level agreements because each has its own skills advantages and cost savings advantages.

For the long term benefit of all stakeholders, it is important to structure a deal in which all parties benefit from optimal operations of the microgrid. Therefore, the SPE revenue and profitability must be in balance with savings to the community off-takers. The appropriate O&M approach for the Canton Community Microgrid has not yet been determined.

System development will involve a complex permitting process. In Stage 2, the team will conduct an environmental assessment that includes CHP air emissions, PV and ESS recycle potential, inverter recycle potential, and visual pollution. The CHP systems will require air quality operating permits, but all proposed systems will qualify for permitting.

The local utility will need to approve of the design of the switching that provides disconnect, islanding, and restoration functions in case of power disruption. The utility will also need to approve plans to use sections of utility distribution equipment while in island mode.

The utility will coordinate protection and switching schemes for the points of common coupling and the distribution system. The project team will address these needs in the interconnection agreement and the studies that support it. The approach to points of common coupling simplifies the interconnection agreement and studies for the utility. This is due to the straight-forward approach taken to isolate the microgrid from the distribution grid with control by the utility in accordance with the Institute of Electrical and Electronics Engineers 1547 interconnection standard. This gives the utility more control and makes the interconnection agreement easier to approve.

The project team recommends that only underground cabling be used to connect loads in the Canton Community Microgrid. Overhead distribution lines do not provide the resiliency or reliability required to meet the specified uptime requirements. Ownership of new purchased and installed underground cabling could be retained by the SPE or gifted to the utility, based on the objectives of community stakeholders. The REV proceedings include a consideration of such arrangements.

If the utility owns the underground cable, then the utility may charge full delivery charges, or "freight," to the customers. This will likely not be the case if the microgrid project paid for the underground cable. A full freight policy, based on past practice and not true value, eliminates nearly all the community's financial benefit associated with the microgrid. This may become an issue for consideration under REV, and is policy recommendation that the project team supports.

Operation of the microgrid will include several key components:

Metering: The SPE will require the state of New York to allow sub-metering that can be applied to the microgrid. The project team recommends new sub-metering is added as necessary.

Technical Operations: The microgrid controls and microgrid design are based on the ten Oak Ridge National Laboratory Microgrid Use Cases. The most important use cases address transition to an island mode (planned and unplanned) and return to grid-connected operations. If selected for stage 2, Hitachi can provide a very detailed sequence of operations for transitioning to island and back to grid-connected mode.

Under normal conditions, the microgrid will operate under one of two regimes to accommodate its nodal structure. The first regime is local (within each node) where optimization is primarily focused on assurance of reliable and resilient operations. The second regime is global – across the entire microgrid – where optimization includes economic and emissions reduction objectives. At the global microgrid level, operations are focused on savings to the community and reduction of emissions.

Financial Operations: The SPE will bill system off-takers monthly for energy from system resources. The project team recommends a simplified approach, billing consumed $/kWh monthly instead of the 18+ billing determinants in a typical utility electric bill. Depending on how the SPE is established with the community, the customer may still be billed by the utility. To simplify bill management for the customers of the microgrid, the utility bill may become a pass-through within the microgrid billing.

Transactional: Any additional revenue to customers from shared utility program participation (demand response, ancillary services) will be accounted for in the monthly bill that the customer receives from the SPE.

PROJECT TEAM

The success of this project relies on a strong team to take it from a feasibility study to an operational system. This Canton Community Microgrid team has engaged with nearly all of the major community stakeholders. Local government representatives and University participants from Canton have led this project from the beginning, and have signaled Canton's clear interest in participating in a microgrid that can deliver resilient, cost effective energy. The community has not stated interest in any kind of public-private partnership at this time, but the project team will continue to consider the potential benefits of such an approach as the project is designed. This may take the form of partial ownership of the SPE by one or more local government agencies.

Other stakeholders have been kept informed throughout the process and have assisted the study by supporting site audits, providing facility information, and participation in regular status calls. As this project enters the next phase, the project team will hold face-to-face meetings with participants to review the results of the feasibility study and confirm their interest in participating in the microgrid through a development agreement.

National Grid and St. Lawrence Gas are aware of this project, provided letters of support for the initial feasibility study and participated in the project kick-off meeting. Throughout the process, the project team has engaged National Grid in design discussions through there RFI process. As of this date, National Grid has not yet weighed in on the value of this project based on the results of the feasibility study. The plan for locations and preliminary sizes of new CHP systems was shared with St. Lawrence Gas. They evaluated the plan and indicated that the local natural gas infrastructure can support the added load attributed to the new CHP systems. Several customers will require upgrades to their service to accommodate the pressure and volume needed for the CHP units.

If the Canton community decides to move forward with the microgrid project, they will need to engage partners to fill the following roles:

- Project Leader
- Project Financiers
- Microgrid Control Provider
- Energy Procurement Contractor (EPC)
- CHP Design Firm
- PV System Design Firm
- Operations and Maintenance Firm
- Legal and Regulatory Advisor

LEGAL VIABILITY

The project team has developed a model for the legal organization of the Canton Community Microgrid based on ownership by a dedicated SPE. The project team has proven the legal viability of this model through numerous existing microgrid projects. This ownership structure maximizes opportunity for low-cost financing, and helps to ensure that final customer rates are kept as low as possible. The ultimate owner of the microgrid system has not been finalized at this point.

Other team members or community stakeholders may decide to take an ownership stake in the system. However, at this time, no community customers or stakeholders have expressed interest in an ownership role.

The SPE will not own the real estate or facilities in which microgrid systems and equipment will be installed. In each case these sites are owned by customers included in the microgrid. These customers have been included in the planning process throughout the feasibility study. Representatives for each accompanied the project team as they walked through the sites following the kick-off meeting, they have worked with the project team to gather data necessary to construct the model, and they will be included in the project close-out meeting. In each step of the process the project team has discussed plans for locating microgrid equipment at each site with the customers who own that site, and have received their provisional approval.

Market Barriers

There are a number of variables which could impact the viability of the project, even if the technical and economic fundamentals look strong. They include:

Financing: There may be aspects of the current market that make securing financing at a competitive cost of capital more difficult. The primary barrier is the education level and familiarity with microgrids within the finance sector. While solar PPAs are now a well-established financing opportunity, only ten years ago, they were little understood by financiers. Today, microgrids are not as well understood in the financial sector. The financial industry has not yet created standardized financing products for microgrids, and each new project has required a custom deal. This tends to drive up the cost of capital.

Stage 2 NY Prize Funding: Stage 1 funding was not sufficient to cover the costs of a comprehensive feasibility study. This was anticipated, and many organizations involved in the delivery engaged in cost sharing and were prepared to make significant investments to deliver a high quality and reliable study for the Canton feasibility study. However, given the levels of investment required of vendors in Stage 1, there will be little appetite or ability to incur additional cost share or risk in Stage 2. This is exacerbated by the inherent risks and known and unknown costs associated with the next phase of development, many of which are specific to community microgrids. Stage 2 funding is critical to moving forward to the next stage of project development.

Customer Commitments: The project economics are highly sensitive to the microgrid design. The design is dependent on customer sites and loads, and the distributed energy resources planned for those locations. A major risk is posed by the possibility of customers withdrawing before final contracts are signed. This would affect the overall microgrid design and fundamental project economics.

Utility Cooperation: The negotiation of interconnection agreements with local utilities can cause significant delays and lead to new costs when the proposed microgrid concepts are unfamiliar to the utility's staff and engineering contractors. To date, National Grid has demonstrated general understanding of the approach and has not identified any deal killers so far. They will provide more detailed input to the design and interface requirements in the detailed engineering stage following this study. Through continued collaboration and sharing of design details, Canton can expect this risk to be fairly small in the next phase.

Regulatory Issues

The ownership model of the Canton Community Microgrid will influence the type of regulatory status it has under Public Service Law. This report assumes that the system will be owned by a third-party SPE. Privately-owned microgrids are legal in New York.

The system will not be considered an electric distribution company by the public services commission because it utilizes qualifying forms of generation,[1] is under 80 MW,[2] serves a qualifying

[1] Qualifying generation facilities are defined in PSL § 2 as those falling under the definitions of "Co-generation facilities," "Small hydro facilities," or "Alternate energy production facilities." A qualifying co-generation [1]
[2]Qualifying generation facilities are defined in PSL § 2 as those falling under the definitions of "Co-generation

number of users, and its related facilities (including any private distribution infrastructure) are located "at or near" its generating facilities. This saves the system from a raft of burdensome regulatory requirements.

Placing distribution wires or leveraging the existing utility distribution system for energy sharing between facilities will be subject to state-wide electric utility regulations, local franchise and rights of way statutes, and the willingness of the local utility.

Privacy

Ensuring the privacy of the microgrid clients will be of paramount importance for both customer satisfaction and project replicability. The project team has taken steps to improve the privacy of all stakeholder data, including all utility data, plans, diagrams and site specific and sensitive information. The project team has done this by setting up a secure data site which allows our team to minimize access of this data to only those directly involved in the modeling and design process. This tightened data control will ensure the project stakeholder's data meets all privacy requirements.

CONCLUSIONS AND NEXT STEPS

The NY Prize feasibility assessment indicates that the Canton Community Microgrid is technically viable and is potentially economically viable with additional NY Prize grants. As a rural, lower income community, Canton is especially well positioned to yield lessons for the rest of New York State and beyond. The project team believes that the proposed microgrid design will serve as a leading example for New York and will be beneficial and replicable to hundreds of other communities across the State and beyond. The feasibility assessment yielded several key findings:

1. ***Engaged Stakeholders*:** The Canton Community Microgrid is built around a set of facilities and institutions that are well established, and committed to the project. There are two universities among this group. This is a unique characteristic of the Canton project, and presents unique opportunities and challenges. The universities in the Canton Community Microgrid have the largest loads, and the lowest cost of electricity. This set's a very high bar for the microgrid business model, in terms of matching this rate and still covering costs.

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facilities," "Small hydro facilities," or "Alternate energy production facilities." A qualifying co-generation facility is defined as "Any facility with an electric generating capacity of up to eighty megawatts…. together with any related facilities located at the same project site, which is fueled by coal, gas, wood, alcohol, solid waste refuse-derived fuel, water or oil, …. and which simultaneously or sequentially produces either electricity or shaft horsepower and useful thermal energy that is used solely for industrial and/or commercial purposes." NY PSL § 2-a. A qualifying small hydro facility is defined as "Any hydroelectric facility, together with any related facilities located at the same project site, with an electric generating capacity of up to eighty megawatts." NY PSL § 2-c. A qualifying "alternate energy production facility is defined as "Any solar, wind turbine, fuel cell, tidal, wave energy, waste management resource recovery, refuse-derived fuel or wood burning facility, together with any related facilities located at the same project site, with an electric generating capacity of up to eighty megawatts, which produces electricity, gas or useful thermal energy." NY PSL Ser § 2-b.

[2] Id.

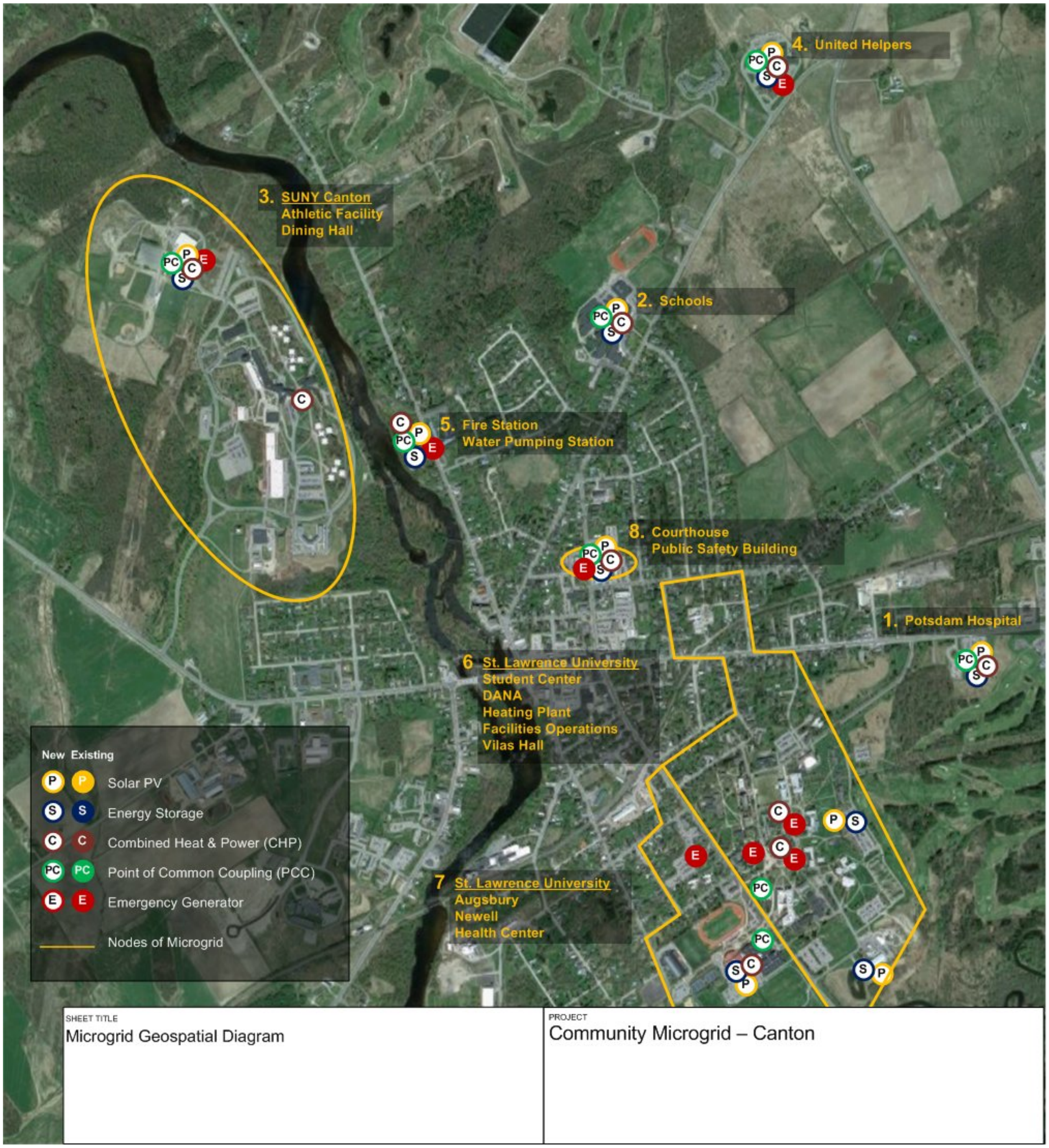
2. ***Remote Net Metering Projects***: Several stakeholders in the Canton Community Microgrid are considering remote net metering projects. These PV installations affect microgrid sizing and economics. Although the projects may represent an attractive financial opportunity for the stakeholders involved, they will not improve energy resilience, as the microgrid would, because they are not designed to provide islanding capability to the facilities at which they are installed.
3. ***Natural Gas Costs***: The cost of natural gas for CHP is not firm. The estimate that the project team used for the financial analysis was made using available data from St. Lawrence gas and assumptions based on distributed generation discounts from other New York utilities. However, going forward, the project team will need to work closely with St. Lawrence Gas to establish a final, firm natural gas rate for the CHP installations included in the microgrid plan.
4. ***Community Microgrid Financing Costs***: The cost of project financing is high for community microgrids. This is due to the fact that there are numerous stakeholders and potential customers, and that each stakeholder has its own procurement requirements. The project team will need to seek out a financier that is knowledgeable about these projects, and can help keep transaction costs to a minimum.
5. ***Financial Prospects:*** As it stands, the Canton Community Microgrid project is not likely to meet the financial requirements for third party financing and ownership. In order to meet these requirements, one or more of the following conditions would need to be met:
    a. The award of Stage 2 or Stage 3 NY Prize grants from NYSERDA
    b. The inclusion of additional commercial customers with higher electric costs
    c. The use of PPA rates above the current average cost of energy for prospective microgrid customers.

Based on the findings of this feasibility analysis, there are several next steps for the project team to undertake. First, the project team should solicit confirmation from each stakeholder that they are interested in continuing to participate in this effort to build a community microgrid. The team may also consider identifying additional facilities that may be good candidates for design consideration based on their criticality and potential to improve project economics. Based on the final customer list, the project should be remodeled project to estimate the technical and economic impact of any additions or subtractions.

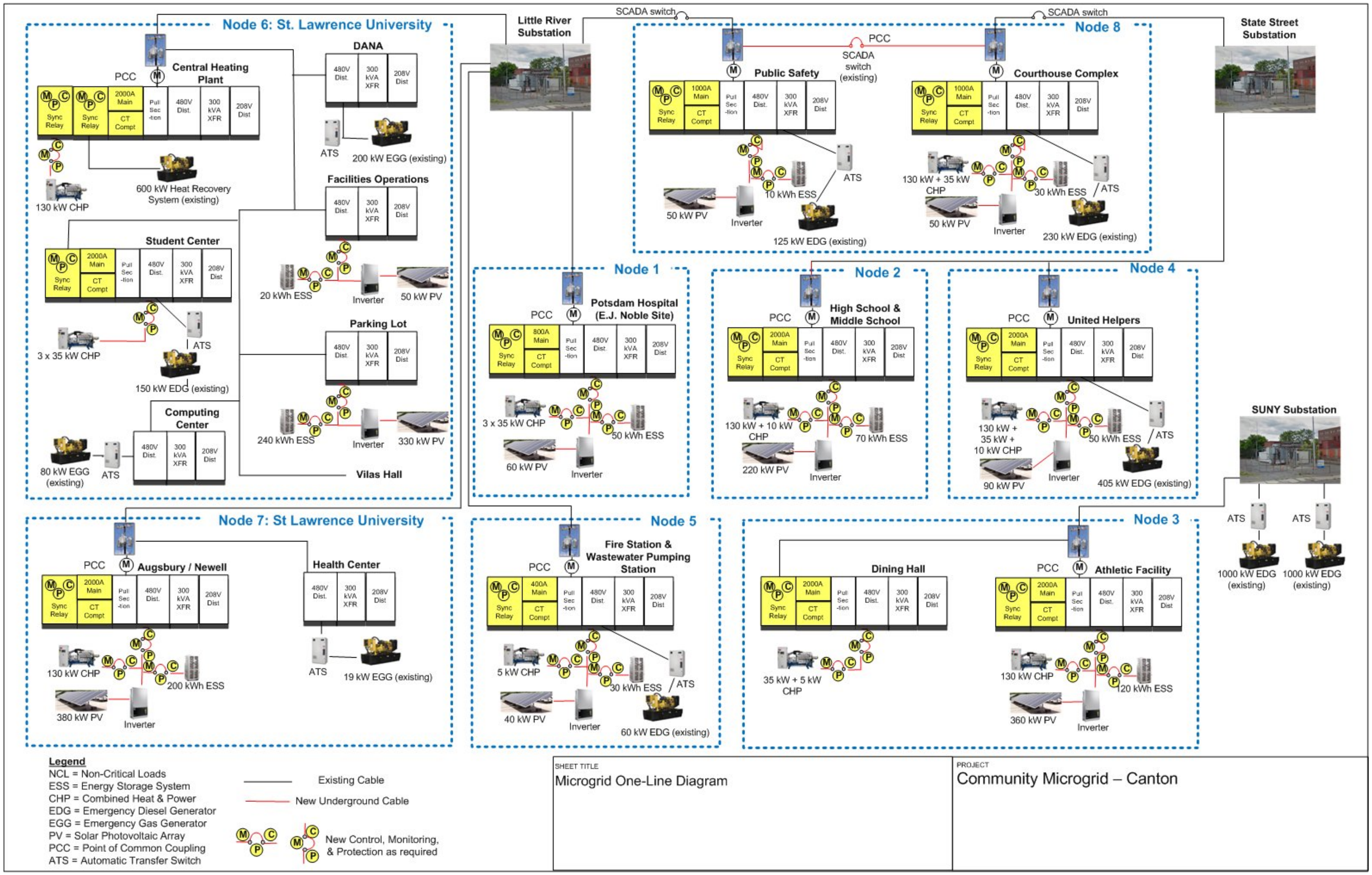
Once the model is final the project team will need to make a go/no go decision about moving forward. If a decision is made to move forward, a project team will need to be finalized. This team will draft a proposal to NYSERDA to compete in Stage 2 of NY Prize. This Stage 2 funding will help defray the additional cost and risk associated with a multi-stakeholder community microgrid. Stage 2 will require cost share, and a determination should be made about which parties will assume this cost.

[End of Report]

APPENDIX A: CANTON MICROGRID LAYOUT DIAGRAM



APPENDIX B: CANTON MICROGRID ONE-LINE DIAGRAM



APPENDIX C: ACRONYM GLOSSARY

- ATS- automatic transfer switch
- BTU – British Thermal Unit
- CCA- community choice aggregation
- CHP- combined heat and power plants
- DER- Distributed Energy Resources
- DHW- domestic hot water
- DMS- distribution management system
- EDG- emergency diesel generator
- EEM- energy efficiency measures
- EGG- emergency gas generator
- EPC- Engineering Procurement Contractor
- EPRI- Electric Power Research Institute
- ESS- energy storage systems
- GHG- greenhouse gases
- Hr - hour
- IEEE- Institute of Electrical and Electronics Engineers
- ISO- independent system operators
- IT – information technology
- ITC- Investment Tax Credit
- kBTU – 1,000 BTU
- kV - kilovolt
- kW – kilowatt
- kWh – kilowatt-hour
- LAN- local area network
- Li-ion- lithium ion
- MW - megawatt
- NOC - Network Operations Center
- NREL- National Renewable Energy Laboratory
- NYSERDA- New York State Energy Research and Development Authority
- O&M- operations and maintenance
- ORNL- Oak Ridge National Laboratory
- PCC - point of common coupling
- PLC- programmable logic controller

- PPA- power purchase agreement
- PV- solar photovoltaics
- REV- Reforming the Energy Vision
- RFI- request for information
- RFP- request for proposals
- RTO- Regional Transmission Organizations
- SCADA – supervisory control and data acquisition
- SGIP- Smart Grid Interoperability Panel
- SOC- state of charge
- SPE- special purpose entity

APPENDIX D: IEC BENEFIT-COST ANALYSIS

Benefit-Cost Analysis Summary Report

Site 59 – Town of Canton

PROJECT OVERVIEW

As part of NYSERDA's NY Prize community microgrid competition, the Town of Canton has proposed development of an eight-node microgrid that would enhance the resiliency of electric service for the following facilities in this North Country community:

- Canton-Potsdam Hospital's E. J. Noble facility, a center for primary health care and other outpatient services;
- Hugh C. Williams High School and J. M. McKenney Middle School;
- Chaney Dining Center and the Convocation Athletic and Recreation Center at SUNY Canton;
- The United Helpers Maplewood Campus, which includes a health care and rehabilitation center, assisted living residences, and residences for patients requiring skilled nursing care;
- The Canton Fire Department's station on Riverside Drive, coupled with a nearby water pumping station;
- The Health and Counseling Center, Augsbury Physical Education Center, and Newell Field House at St. Lawrence University (SLU);
- SLU's Computing Center, Dana Dining Center, Facilities Operations Building, Kinsley Heating Plant, Sullivan Student Center, and Vilas Hall; and
- The St. Lawrence County Courthouse and Public Safety Complex, which houses state and county courts, an emergency response center, and the County Sherriff's Department.

A number of these facilities – including the public schools and dining and athletic complexes at SUNY Canton and SLU – have been incorporated into the proposal as emergency shelters for local residents.

The Canton microgrid would incorporate combined heat and power (CHP) and solar capabilities to provide base load power. Eighteen gas-fired CHP units would be distributed among the participating facilities; these would range in capacity from 0.005 MW to 0.13 MW. A photovoltaic (PV) array at each node of the microgrid would supplement the CHP systems. The solar installations would add 1.63 MW of capacity to the system. In addition, a battery storage system and energy efficiency measures would be incorporated at each node of the microgrid; the battery capacity included in the microgrid totals 1.392 MW. The operating scenario submitted by the project's consultants indicates that these new resources together would produce approximately 10,749 MWh of electricity per year, roughly 83 percent of the amount required to meet the average annual energy requirements of the facilities listed above. To supplement these sources during a major outage, the microgrid would incorporate 10 emergency generators with a total capacity of 3.469 MW. The capacity of these generators – which are already in place, and would only be employed in islanded mode – is sufficient to ensure that the system as a whole could supply 100 percent of average electricity use at the facilities served by the microgrid.

To assist with completion of the project's NY Prize Stage 1 feasibility study, IEc conducted a screening-level analysis of the project's potential costs and benefits. This report describes the results of that analysis, which is based on the methodology outlined below.

METHODOLOGY AND ASSUMPTIONS

In discussing the economic viability of microgrids, a common understanding of the basic concepts of benefit-cost analysis is essential. Chief among these are the following:

- *Costs* represent the value of resources consumed (or benefits forgone) in the production of a good or service.
- *Benefits* are impacts that have value to a firm, a household, or society in general.
- *Net benefits* are the difference between a project's benefits and costs.
- Both costs and benefits must be measured relative to a common *baseline* - for a microgrid, the "without project" scenario - that describes the conditions that would prevail absent a project's development. The BCA considers only those costs and benefits that are *incremental* to the baseline.

This analysis relies on an Excel-based spreadsheet model developed for NYSERDA to analyze the costs and benefits of developing microgrids in New York State. The model evaluates the economic viability of a microgrid based on the user's specification of project costs, the project's design and operating characteristics, and the facilities and services the project is designed to support. The model analyzes a discrete operating scenario specified by the user; it does not identify an optimal project design or operating strategy.

The BCA model is structured to analyze a project's costs and benefits over a 20-year operating period. The model applies conventional discounting techniques to calculate the present value of costs and benefits, employing an annual discount rate that the user specifies – in this case, seven percent.[3] It also calculates an annualized estimate of costs and benefits based on the anticipated engineering lifespan of the system's equipment. Once a project's cumulative benefits and costs have been adjusted to present values, the model calculates both the project's net benefits and the ratio of project benefits to project costs. The model also calculates the project's internal rate of return, which indicates the discount rate at which the project's costs and benefits would be equal. All monetized results are adjusted for inflation and expressed in 2014 dollars.

With respect to public expenditures, the model's purpose is to ensure that decisions to invest resources in a particular project are cost-effective; i.e., that the benefits of the investment to society will exceed its

[3] The seven percent discount rate is consistent with the U.S. Office of Management and Budget's current estimate of the opportunity cost of capital for private investments. One exception to the use of this rate is the calculation of environmental damages. Following the New York Public Service Commission's (PSC) guidance for benefit-cost analysis, the model relies on temporal projections of the social cost of carbon (SCC), which were developed by the U.S. Environmental Protection Agency (EPA) using a three percent discount rate, to value CO_2 emissions. As the PSC notes, "The SCC is distinguishable from other measures because it operates over a very long time frame, justifying use of a low discount rate specific to its long term effects." The model also uses EPA's temporal projections of social damage values for SO_2, NO_x, and $PM_{2.5}$, and therefore also applies a three percent discount rate to the calculation of damages associated with each of those pollutants. [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.]

costs. Accordingly, the model examines impacts from the perspective of society as a whole and does not identify the distribution of costs and benefits among individual stakeholders (e.g., customers, utilities). When facing a choice among investments in multiple projects, the "societal cost test" guides the decision toward the investment that produces the greatest net benefit.

The BCA considers costs and benefits for two scenarios:

- Scenario 1: No major power outages over the assumed 20-year operating period (i.e., normal operating conditions only).
- Scenario 2: The average annual duration of major power outages required for project benefits to equal costs, if benefits do not exceed costs under Scenario 1.[4]

RESULTS

Table 1 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for the scenarios described above. The results indicate that if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to equal or exceed 0.5 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

Table 1. BCA Results (Assuming 7 Percent Discount Rate)

ECONOMIC MEASURE	ASSUMED AVERAGE DURATION OF MAJOR POWER OUTAGES	
	SCENARIO 1: 0 DAYS/YEAR	SCENARIO 2: 0.5 DAYS/YEAR
Net Benefits - Present Value	-$3,610,000	$424,000
Benefit-Cost Ratio	0.8	1.0
Internal Rate of Return	-0.6%	6.5%

Scenario 1

Figure 1 and Table 2 present the detailed results of the Scenario 1 analysis.

[4] The New York State Department of Public Service (DPS) requires utilities delivering electricity in New York State to collect and regularly submit information regarding electric service interruptions. The reporting system specifies 10 cause categories: major storms; tree contacts; overloads; operating errors; equipment failures; accidents; prearranged interruptions; customers equipment; lightning; and unknown (there are an additional seven cause codes used exclusively for Consolidated Edison's underground network system). Reliability metrics can be calculated in two ways: including all outages, which indicates the actual experience of a utility's customers; and excluding outages caused by major storms, which is more indicative of the frequency and duration of outages within the utility's control. In estimating the reliability benefits of a microgrid, the BCA employs metrics that exclude outages caused by major storms. The BCA classifies outages caused by major storms or other events beyond a utility's control as "major power outages," and evaluates the benefits of avoiding such outages separately.

Figure 1. Present Value Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)

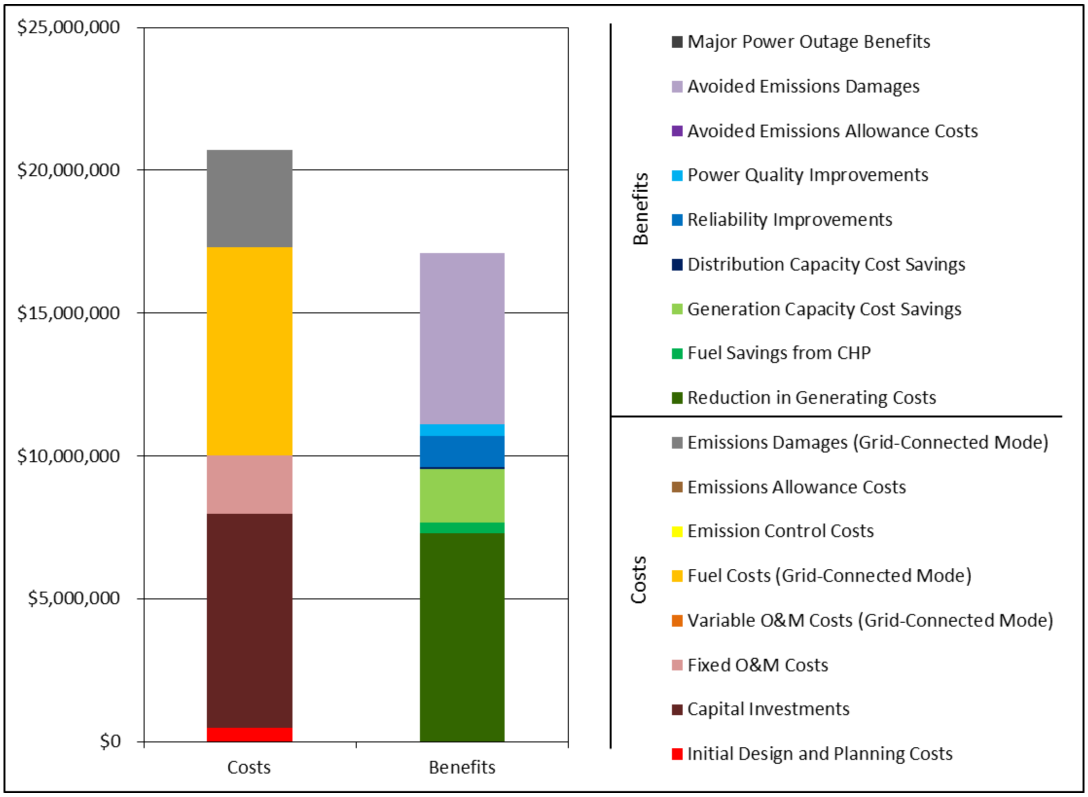


Table 2. Detailed BCA Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$475,000	$41,900
Capital Investments	$7,500,000	$598,000
Fixed O&M	$2,040,000	$180,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$7,300,000	$644,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$3,390,000	$222,000
Total Costs	**$20,700,000**	
Benefits		
Reduction in Generating Costs	$7,300,000	$644,000
Fuel Savings from CHP	$357,000	$31,500
Generation Capacity Cost Savings	$1,880,000	$166,000
Distribution Capacity Cost Savings	$67,300	$5,940
Reliability Improvements	$1,080,000	$95,400
Power Quality Improvements	$426,000	$37,600
Avoided Emissions Allowance Costs	$3,820	$337
Avoided Emissions Damages	$5,980,000	$390,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$17,100,000**	
Net Benefits	**-$3,610,000**	
Benefit/Cost Ratio	**0.8**	
Internal Rate of Return	**-0.6%**	

Fixed Costs

The BCA relies on information provided by the project team to estimate the fixed costs of developing the microgrid. The project team's best estimate of initial design and planning costs is approximately $475,000.[5] The present value of the project's capital costs is estimated at approximately $7.50 million, including costs associated with installing the new CHP units, PV arrays, battery storage, and associated microgrid infrastructure (controls, communication systems, information technology, etc.). The present value of the microgrid's fixed operations and maintenance (O&M) costs (i.e., O&M costs that do not vary with the amount of energy produced) is estimated at $2.04 million, based on an annual cost of $180,000.

[5] The project's consultants note that this estimate is based on the costs of developing the power purchase agreement (PPA), negotiating other contracts, and arranging financing and insurance. It represents an average cost estimate; the actual costs ultimately incurred may be higher or lower, depending on the complexity of the site.

Variable Costs

A significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the system's 18 CHP units. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the project team and projections of fuel costs from New York's 2015 State Energy Plan (SEP), adjusted to reflect recent market prices.[6] Based on these figures, the present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $7.30 million.

In addition, the analysis of variable costs considers the environmental damages associated with pollutant emissions from the distributed energy resources that serve the microgrid, based on the operating scenario and emissions rates provided by the project team and the understanding that none of the system's generators would be subject to emissions allowance requirements. In this case, the damages attributable to emissions from the microgrid's CHP units are estimated at approximately $222,000 annually. The majority of these damages are attributable to the emission of CO_2. Over a 20-year operating period, the present value of emissions damages is estimated at approximately $3.39 million.

Avoided Costs

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. These include generating cost savings resulting from a reduction in demand for electricity from bulk energy suppliers. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $7.30 million; this estimate takes into account both the electricity that the microgrid's CHP units and PV arrays would produce and an anticipated reduction in annual electricity use at the facilities the microgrid would serve.[7] In addition, the new CHP systems would cut consumption of natural gas for heating purposes; the present value of these savings over the 20-year period analyzed is approximately $357,000. The reduction in demand for electricity from bulk energy suppliers and reduction in the amount of fuel needed for heating purposes would also reduce emissions of air pollutants, yielding emissions allowance cost savings with a present value of approximately $3,820 and avoided emissions damages with a present value of approximately $5.98 million.[8]

In addition to the savings noted above, development of a microgrid could yield cost savings by avoiding or deferring the need to invest in expansion of the conventional grid's energy generation or distribution capacity.[9] Based on application of standard capacity factors for the CHP and solar units, as well as the capacity of the battery storage systems, the analysis estimates the present value of the project's

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[6] The model adjusts the State Energy Plan's natural gas and diesel price projections using fuel-specific multipliers calculated based on the average commercial natural gas price in New York State in October 2015 (the most recent month for which data were available) and the average West Texas Intermediate price of crude oil in 2015, as reported by the Energy Information Administration. The model applies the same price multiplier in each year of the analysis.

[7] The project's consultants anticipate an annual reduction in electricity consumption of four percent due to energy efficiency upgrades included with the microgrid.

[8] Following the New York Public Service Commission's (PSC) guidance for benefit cost analysis, the model values emissions of CO_2 using the social cost of carbon (SCC) developed by the U.S. Environmental Protection Agency (EPA). [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.] Because emissions of SO_2 and NO_x from bulk energy suppliers are capped and subject to emissions allowance requirements in New York, the model values these emissions based on projected allowance prices for each pollutant.

[9] Impacts to transmission capacity are implicitly incorporated into the model's estimates of avoided generation costs and generation capacity cost savings. As estimated by NYISO, generation costs and generating capacity costs vary by location to reflect costs imposed by location-specific transmission constraints.

generating capacity benefits to be approximately $1.88 million over a 20-year operating period. Similarly, the project team estimates that the microgrid project would reduce the need for local distribution capacity by approximately 0.1625 MW/year, yielding annual benefits of approximately $5,940. Over a 20-year period, the present value of these benefits is approximately $67,300.

The project team has indicated that the proposed microgrid would be designed to provide ancillary services to the New York Independent System Operator (NYISO). Whether NYISO would select the project to provide these services depends on NYISO's requirements and the ability of the project to provide support at a cost lower than that of alternative sources. Based on discussions with NYISO, it is our understanding that the markets for ancillary services are highly competitive, and that projects of this type would have a relatively small chance of being selected to provide support to the grid. In light of this consideration, the analysis does not attempt to quantify the potential benefits of providing these services.

Reliability Benefits

An additional benefit of the proposed microgrid would be to reduce customers' susceptibility to power outages by enabling a seamless transition from grid-connected mode to islanded mode. The analysis estimates that development of a microgrid would yield reliability benefits of approximately $95.400 per year, with a present value of $1.08 million over a 20-year operating period. This estimate was developed using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, and is based on the following indicators of the likelihood and average duration of outages in the service area:[10]

- System Average Interruption Frequency Index (SAIFI) – 0.96 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 116.4 minutes.[11]

The estimate takes into account the number of small and large commercial or industrial customers the project would serve; the distribution of these customers by economic sector; average annual electricity usage per customer, as provided by the project team; and the prevalence of backup generation among these customers. It also takes into account the variable costs of operating existing backup generators, both in the baseline and as an integrated component of a microgrid. Under baseline conditions, the analysis assumes a 15 percent failure rate for backup generators.[12] It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

It is important to note that the analysis of reliability benefits assumes that development of a microgrid would insulate the facilities the project would serve from outages of the type captured in SAIFI and CAIDI values. The distribution network within the microgrid is unlikely to be wholly invulnerable to such interruptions in service. All else equal, this assumption will lead the BCA to overstate the reliability benefits the project would provide.

Power Quality Benefits

The power quality benefits of a microgrid may include reductions in the frequency of voltage sags and swells or reductions in the frequency of momentary outages (i.e., outages of less than five minutes, which are not captured in the reliability indices described above). The analysis of power quality benefits relies on the project team's best estimate of the number of power quality events that development of the microgrid would avoid each year. The Canton team estimates that the facilities served by the microgrid

[10] www.icecalculator.com.

[11] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for National Grid.

[12] http://www.businessweek.com/articles/2012-12-04/how-to-keep-a-generator-running-when-you-lose-power#p1.

would avoid an average of approximately 1.66 such events annually. The model estimates the present value of this benefit to be approximately $426,000 over a 20-year operating period.

Summary

The analysis of Scenario 1 yields a benefit/cost ratio of 0.8; i.e., the estimate of project benefits is approximately 80 percent that of project costs. Accordingly, the analysis moves to Scenario 2, taking into account the potential benefits of a microgrid in mitigating the impact of major power outages.

Scenario 2

Benefits in the Event of a Major Power Outage

As previously noted, the estimate of reliability benefits presented in Scenario 1 does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.[13,14]

As noted above, the Town of Canton's proposed microgrid project would serve a large number of critical facilities. At present, many of these facilities are equipped with emergency generators; others could rent a portable generator in the event of a prolonged outage. Table 3 summarizes the estimated cost of operating these generators; the estimate of daily operating costs includes the cost of fuel as well as other daily costs of operation. Table 3 also indicates the loss in service capabilities that is likely to occur while relying on these units, as well as the loss in service capabilities that would occur should these units fail. The information the table provides serves as an input to our analysis of the costs associated with a major power outage, based on the following assumptions:

- In all cases, the supply of fuel necessary to operate the backup generators would be maintained indefinitely.
- In all cases, there is a 15 percent chance that the backup generator would fail.

The costs of a major outage also depend on the consequences of a sustained interruption of service at the facilities of interest. The analysis calculates the impact of a loss in fire, emergency medical, police, and wastewater services using standard FEMA methodologies.[15] The impact of a loss in service at the remaining facilities is based on the following value of service estimates:

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[13] The methodology used to estimate the value of lost services was developed by the Federal Emergency Management Agency (FEMA) for use in administering its Hazard Mitigation Grant Program. See: FEMA Benefit-Cost Analysis Re-Engineering (BCAR): Development of Standard Economic Values, Version 4.0. May 2011.

[14] As with the analysis of reliability benefits, the analysis of major power outage benefits assumes that development of a microgrid would insulate the facilities the project would serve from all outages. The distribution network within the microgrid is unlikely to be wholly invulnerable to service interruptions. All else equal, this will lead the BCA to overstate the benefits the project would provide.

[15] The Canton Fire Department operates three ambulances that provide emergency medical services to residents of the Canton area. http://www.cantonfirerescue.com/content/appcurrent/. The water pumping station that would be supported by the microgrid is an element of the community's sewer and wastewater treatment systems.

- For Canton-Potsdam Hospital's E.J. Noble building; SUNY Canton's Chaney Dining Center; United Helpers; the County Courthouse; and SLU's Computing Center, Health and Counseling Center, Heating Plant, Facilities Operations Building, and Vilas Hall, a total value of approximately $610,159 per day. This figure was estimated using the ICE Calculator, assuming 24 hours of microgrid demand per day during an outage.[16]

- For all remaining facilities, a total value of approximately $867,800 per day, reflecting their potential use as emergency shelters. This figure is based on the Canton team's estimate of the facilities' shelter capacity and a standard value from the Red Cross of $50 per person per day for food and shelter.[17]

Table 3. Costs and Level of Service Maintained by Backup Generators, Scenario 2

FACILITY	ONE-TIME COSTS ($)	ONGOING OPERATING COSTS ($/DAY)	PERCENT LOSS IN SERVICE CAPABILITIES DURING AN OUTAGE	
			WITH BACKUP POWER	WITHOUT BACKUP POWER
Canton-Potsdam Hospital E. J. Noble Facility[1]	$700	$1,081	80%	100%
Hugh C. Williams High School and J. M. McKenney Middle School[2]	$1,500	$2,850	80%	100%
SUNY Canton – Athletic Center and Chaney Dining Center[1]	$0	$1,858	10%	90%
SUNY Canton – Chaney Dining Center[1]			0%	90%
United Helpers[1]	$0	$!,343	0%	100%
Canton Fire Department & Water Pumping Station[1]	$0		0%	80%
SLU – Augsbury Physical Education Center & Newell Field House[2]	$500	$1,000	10%	90%
SLU – Health and Counseling Center[1]	$0	$790	10%	100%
SLU – Computing Center[1]	$0	$847	0%	100%
SLU – Dana Dining Center[1]	$0	$914	10%	90%
SLU – Facilities Operations Building[2]	$500	$1,000	10%	90%
SLU – Kinsley Heating Plant[2]	$500	$1,000	10%	90%
SLU – Sullivan Student Center[1]	$0	$1,093	10%	90%
SLU – Vilas Hall[2]	$500	$1,000	10%	90%
St. Lawrence County Courthouse[1]	$1,000[3]	$1,174	20%	100%
Public Safety Complex[1]	$0	$906	0%	10%

[16] http://icecalculator.com/.

[17] The standard value from the Red Cross of $50 per person per day for food and shelter is from: American Red Cross. 2014. Fundraising Dollar Handles for Disaster Relief Operations. Revised March 2014 based on FY14 figures. Accessed March 17, 2016 at http://www.redcross.org/images/MEDIA_CustomProductCatalog/m30240126_FY14FundraisingDollarHandles.pdf.

FACILITY	ONE-TIME COSTS ($)	ONGOING OPERATING COSTS ($/DAY)	PERCENT LOSS IN SERVICE CAPABILITIES DURING AN OUTAGE	
			WITH BACKUP POWER	WITHOUT BACKUP POWER

Notes:

[1] Existing backup generator.

[2] Rented generator.

[3] In addition to a one-time cost of $1,000 to rent a generator, the project's consultants estimate a one-time cost of $1,000 to relocate the New York State Court to the Supreme Court courtroom while operating on emergency power. The cost of this emergency measure is taken into account in calculating the costs associated with an extended power outage.

Summary

Figure 2 and Table 4 present the results of the BCA for Scenario 2. The results indicate that the benefits of the proposed project would equal or exceed its costs if the project enabled the facilities it would serve to avoid an average of 0.5 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

Figure 2. Present Value Results, Scenario 2 (Major Power Outages Averaging 0.5 Days/Year; 7 Percent Discount Rate)

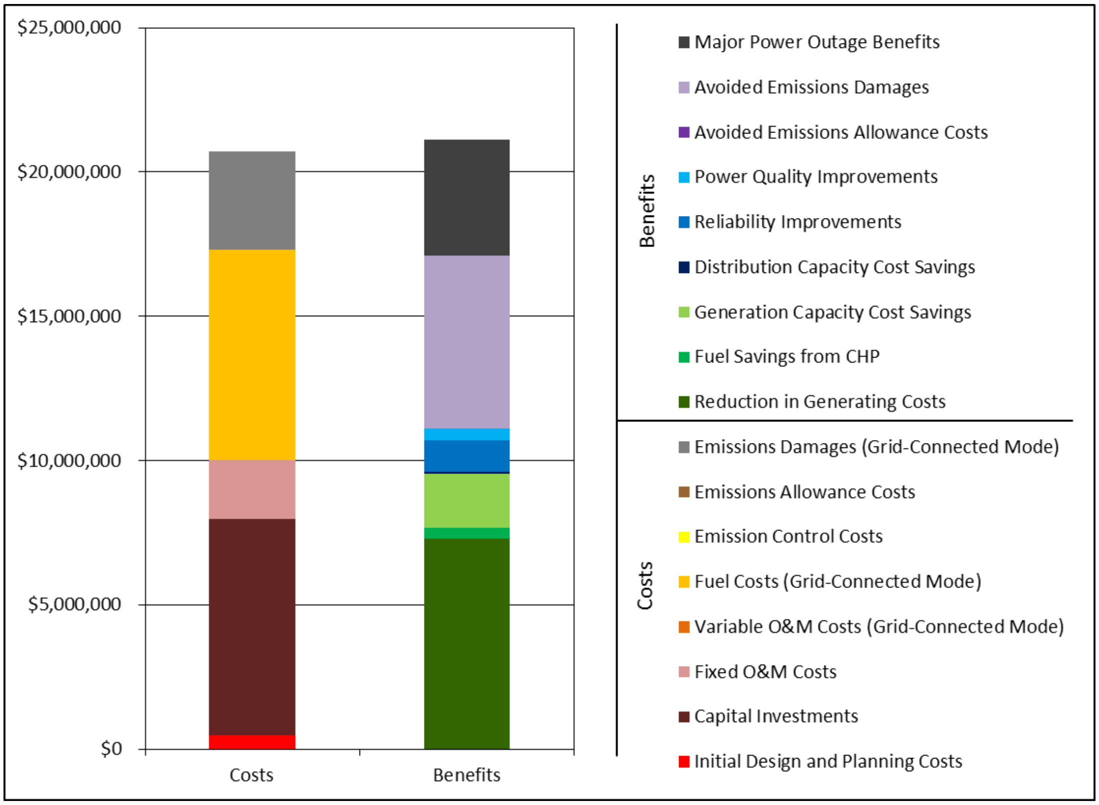

Table 4. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 0.5 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$475,000	$41,900
Capital Investments	$7,500,000	$598,000
Fixed O&M	$2,040,000	$180,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$7,300,000	$644,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$3,390,000	$222,000
Total Costs	**$20,700,000**	
Benefits		
Reduction in Generating Costs	$7,300,000	$644,000
Fuel Savings from CHP	$357,000	$31,500
Generation Capacity Cost Savings	$1,880,000	$166,000
Distribution Capacity Cost Savings	$67,300	$5,940
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Power Quality Improvements	$426,000	$37,600
Avoided Emissions Allowance Costs	$3,820	$337
Avoided Emissions Damages	$5,980,000	$390,000
Major Power Outage Benefits	$4,040,000	$356,000
Total Benefits	**$21,100,000**	
Net Benefits	**$424,000**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**6.5%**	