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Town of Chateaugay Microgrid Feasibility Study

Microgrid Project Results and Final Written Documentation

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Abstract

Together with the Town of Chateaugay (Chateaugay), Booz Allen Hamilton has completed the feasibility study for a proposed microgrid. This study summarizes the findings and recommendations, results, lessons learned, and benefits of the proposed microgrid. The Project Team has determined the project is feasible, though not without challenges. The commercial and financial viability of the project have been analyzed and detailed in this document. The Chateaugay microgrid project will generate positive operating cash flows and recover investment costs. The project is commercially viable without NY Prize Phase III funding, but additional subsidies would make it more attractive to private investors. The microgrid design proposes two new distributed energy resources (DER) – a 200 kilowatt (kW) solar photovoltaic (PV) array and a 3.5 megawatt (MW) natural gas-fired combined heat and power (CHP) system. This portfolio of DERs will provide reliable, low-emission electricity to customers while providing a proof of concept for a community microgrid in an investor-owned utility (IOU) territory. Many of the takeaways of the feasibility study may be generalized across the spectrum of NY Prize and community microgrids.

Keywords: NY Prize, NYSERDA, distributed energy resources, energy resilience, clean energy, DER, Chateaugay

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Acronyms and Abbreviations

AC	Alternating Current
AMI	Advanced Metering Infrastructure
ATS	Automatic Transfer Switch
BCA	Benefit Cost Analysis
BEMS	Building Energy Management Systems
BTU	British thermal unit
CAIDI	Customer Average Interruption Duration Index
CHP	Combined Heat and Power
DC	Direct Current
DER	Distributed Energy Resources
DNP3	Distributed Network Protocol
DPW	Department of Public Works
DR	Demand Response
DSP	Distributed System Platform
EDRP	Emergency Demand Response Program
EE	Energy Efficiency
EMS	Energy Management System
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
Hz	Hertz
ICCP	Inter-Control Center Communications Protocol
IEc	Industrial Economics
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IOU	Investor-Owned Utility
ISM	Industrial Scientific and Medical
IT	Information Technology
ITC	Investment Tax Credit
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt hour
LAN	Local Area Network
LBMP	Location-Based Marginal Price
Mcf	One Thousand Cubic Feet of Natural Gas
MCS	Microgrid Control System
MHz	Megahertz
MMBTU	One Million British Thermal Units
$MMTCO_2e$	Million Metric Tons CO_2 Equivalent
$MTCO_2e$	Metric Tons CO_2 Equivalent
MW	Megawatt
MWh	Megawatt-hour
NYISO	New York Independent System Operator
NYPSC	New York Public Service Commission

NYS DEC	New York State Department of Environmental Conservation
NYSEG	New York State Electric and Gas Corporation
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation and Maintenance
OPC	Open Platform Communication or OLE (Object Link Embedded) Process Control
OPF	Optimal Power Flow
PCC	Point of Common Coupling
PLC	Programmable Logic Controller
PPA	Power Purchase Agreement
PV	Photovoltaic
RAID	Redundant Array of Independent Disks
REV	Reforming the Energy Vision
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SCOPF	Security Constrained Optimal Power Flow
SOA	Service Oriented Architecture
SOW	Statement of Work
SPV	Special Purpose Vehicle
TCP/IP	Transmission Control Protocol/Internet Protocol
T&D	Transmission and Distribution
VAC	Volt Alternating Current

Executive Summary

Booz Allen Hamilton was awarded a contract by the New York State Energy Research and Development Authority (NYSERDA) through its New York Prize initiative to conduct a feasibility study of a community microgrid concept in the Town of Chateaugay. This deliverable presents the findings and recommendations from the previous four tasks, discusses the results and lessons learned from the project, and lays out the environmental and economic benefits for the project. The design demonstrates that the Town can improve energy resilience with emergency island mode capabilities and comply with the greater New York Reforming the Energy Vision (REV) initiative by constructing 3.7 MW of new, clean energy generation capability. The study concludes that the technical design is feasible.

The proposed microgrid includes five facilities and five load clusters: the Fire Station, Department of Public Works (DPW) complex (which includes the Village Office and Storage Facility), McCadam Cheese Company, Chateaugay Town Garage, Primary Water, and five residential load clusters. The McCadam Cheese Company will host the 3.5 MW natural gas CHP unit and 200 kW solar PV array and will consume all of the CHP unit's cogenerated steam. The existing backup generators at the Fire Station and DPW complex will not be connected to the microgrid, but may come on-line in island mode behind the meter to reduce their facilities' loads. The CHP unit will operate continuously throughout the year, exporting energy to the local grid in grid-connected mode and supplying energy to microgrid facilities in islanded mode. The solar PV array will stay on-line throughout the year, but its output will be variable due to weather conditions and insolation. Table ES-1 describes the prospective microgrid facilities, Table ES-2 describes the existing and proposed generation assets, and Figure ES-1 provides their locations on a map.

Table ES-1. Prospective Microgrid Facilities

Table lists the facilities in the Town of Chateaugay's proposed microgrid, including their classifications as public, health, or school. The table also denotes critical and important facilities.

Name on Map	Property	Classification
F1	Fire Station	Public*
F2	Department of Public Works, Village Office, and Storage	Public*
F3	McCadam Cheese Company	Commercial*
F4	Chateaugay Town Garage	Public*
F5	Primary Water	Public*
F6	Load Cluster 1	Residential**
F7	Load Cluster 2	Residential**
F8	Load Cluster 3	Residential**
F9	Load Cluster 4	Residential**
F10	Load Cluster 5	Residential**
	* Critical Facility ** Important Facility	

Table ES-2. Chateaugay Generation Assets

Table lists the distributed energy resources that will be included in the Chateaugay microgrid, including their address, fuel source, and nameplate capacity. The table also provides their labels for Figure ES-1.

Map Label	Description	Fuel Source	Capacity (kW)	Address
DER1	**New CHP System**	Natural Gas	3500	23 Collins St
DER2	**New Solar PV Array**	Sun Light	200	23 Collins St

Figure ES- 1. Schematic of Microgrid with Facilities and DERs

Figure shows the proposed microgrid and the locations of the facilities and DERs in the Chateaugay microgrid.

In order to meet the energy needs of these critical and important facilities, the microgrid system will incorporate the following proposed generation assets.

- 200 kW solar PV array
- 3.5 MW natural gas-fired CHP system

The proposed generation assets should have adequate capacity to provide 100% of the electricity requirements of the facilities. The proposed microgrid includes five facilities and five load clusters: the Fire Station, Department of Public Works (DPW) complex (which includes the Village Office and Storage Facility), McCadam Cheese Company, Chateaugay Town Garage, Primary Water, and five residential load clusters. The McCadam Cheese Company will host the 3.5 MW natural gas CHP unit and 200 kW solar PV array and will consume all of the CHP unit's cogenerated steam. The existing backup generators at the Fire Station and DPW complex will not be connected to the microgrid, but may come on-line in island mode behind the meter to reduce their facilities' loads. The CHP unit will operate continuously throughout the year, exporting energy to the local grid in grid-connected mode and supplying energy to microgrid facilities in islanded mode. The solar PV array will stay on-line throughout the year, but its output will be variable due to weather conditions and insolation. Table ES-1 describes the prospective microgrid facilities, Table ES-2 describes the existing and proposed generation assets, and Figure ES-1 provides their locations on a map.

Table ES-1, above, during emergency outage conditions. When the solar arrays are operating close to their maximum production points, the microgrid's generation capacity will approach 3.7 MW, with 3.5 MW of capacity from spinning generators. Aggregate demand from all facilities proposed within the microgrid footprint averaged 1.255 MW and never exceeded 3.112 MW in 2014. The backup power supplied by the microgrid will ensure essential services remain accessible during long-term grid outages, providing relief for residents in and around the Town of Chateaugay. With the addition of these generation assets, the Town could experience reduced emissions during peak demand events, reduce the need for local diesel backup, and could benefit from a more resilient and redundant energy supply to critical services.

The team proposes a hybrid ownership model, wherein a special purpose vehicle (SPV) owns new distributed energy resources and microgrid components/control infrastructure and operates the DERs. Given the capital expenditures, it is anticipated that the SPV will be owned by private investors. The SPV or a third party operator will operate and maintain the microgrid components and control infrastructure and the proposed DERs. Revenue streams from electricity and thermal sales will accrue to SPV investors and will cover variable generation costs. In Chateaugay, the proposed ownership model provides the greatest benefits to the utility and customer base within the Town, ensuring that revenues and costs are relatively in balance.

The microgrid will incur initial capital costs of $8.2 million as well as yearly operation, maintenance, and fuel costs totaling $1.16 million per year. Overall revenue streams from the project are estimated at $1.7 million per year and will be captured primarily through the sale of electricity during grid-connected mode and the sale of thermal resources to McCadam Cheese Company. Other revenues from the proposed microgrid will include tax credits and incentives.

The Chateaugay microgrid will produce competitive returns for investors. Cash-based value streams will accrue to members of the SPV. Normal operation will produce an operating profit of approximately $540,000 per year, which will recover investment costs and produce positive returns. This figure includes incentives from the NYSERDA CHP Performance Program, NY Sun Program, and Federal investment tax credit (ITC) but no subsidies from the NY Prize program. With NY Prize funding, the Chateaugay microgrid project would become a highly attractive investment.

The Chateaugay microgrid concept, with new reliable and renewable generation and the integration of existing energy resources, provides the Town with an energy resilience solution that is technically sound and, with the NY Prize, financially viable. The ability to island five critical and important facilities, as well as five residential clusters, is a significant addition to the resilience of the Town in times of emergency and extended grid outages.

1. Introduction

The Town of Chateaugay is seeking to develop a community microgrid to improve energy service resilience, accommodate distributed energy resources, and reduce greenhouse gas (GHG) emissions. Working with the Town of Chateaugay and New York State Electric and Gas Corporation (NYSEG), a team from Booz Allen Hamilton (hereafter Booz Allen or the Project Team) designed a preliminary microgrid concept that will connect five critical and important facilities and five residential clusters with two new generation assets. The design proposes a new 3.5 MW natural gas-fired reciprocating generator and a new 200 kW solar PV array. Section 2 of this document describes the configuration further. In this document, the Project Team discusses the observations, findings, and recommendations from the entirety of the analysis. Within the document, Booz Allen also explores avenues for further development, discusses project results, and shares lessons learned regarding configuration, capabilities, environmental and economic benefits, and implementation scenarios.

The Town of Chateaugay and its residents seek to improve the resilience of energy service and lower their environmental footprint. More specifically, the Town faces several challenges that could be mitigated with a community microgrid:

- The Fire Station and DPW complex own emergency back-up generators, but these DERs are not built for continuous operation during a long-term grid outage. A microgrid could ensure critical services and businesses in the Town have a stable, reliable power supply for the entire duration of a long-term power outage by tying a continuous duty CHP unit and a solar PV array to local critical and residential facilities
- Electricity service in the region has occasionally been interrupted by extreme weather events, such as winter storms. A microgrid could provide electricity to critical facilities during extreme weather events, and it may expand in the future to include more homes, businesses, and government buildings
- In order to improve its energy profile and reduce its carbon footprint, the community prefers low-emission options for distributed energy resources. An integrated microgrid adds value to advanced distributed energy resources technologies, increasing the viability of natural gas-fired reciprocating generators or solar arrays
- Additional generation in Chateaugay may mitigate reported voltage fluctuations in the community

2. Microgrid Capabilities and Technical Design and Configuration

This section provides a combined overview of the criteria assessed in Task 1 - Microgrid Capabilities and Task 2 – Technical Design and Configuration. The tasks were combined and address all of the criteria in the following order: microgrid capabilities, DER characterization, load characterization, proposed microgrid infrastructure and operations, electric and thermal infrastructure characterization, microgrid building and controls, and IT and telecommunications infrastructure.

2.1 Project Purpose and Need

NYSERDA and Governor Cuomo recognize the importance of expanding distributed energy resources across the state as a way to improve overall system reliability. A community microgrid offers the ideal approach to linking distributed energy resource assets to critical and important facilities, and will help bring multiple parties together to exceed the minimum necessary load for commercial viability. By providing a local market for energy and an example of DER feasibility, the microgrid will also encourage local investment in distributed energy resource technology, such as solar, wind, and battery storage.

The Chateaugay microgrid will improve the resiliency of the local electricity grid in emergency outage situations, stabilize energy prices during peak events, and expand low-emission distributed energy resources in the area. The Town experiences the usual range of extreme weather that affects upstate New York, including torrential rain, snow, wind, and flooding, all of which may impact the larger grid's ability to safely, reliably, and efficiently deliver services to customers. Winter storms have disrupted the power supply in recent years. Chateaugay is currently supplied by one radial feeder that is not North American Energy Reliability Corporation (NERC) compliant. The microgrid will provide electricity to critical facilities and some residential loads during extreme weather events and may expand in the future to include more homes, businesses, and government buildings.

Chateaugay enjoys the advantage of having five critical facilities along the same feeder, Chateaugay 514. The preliminary design therefore does not require new electric distribution lines to connect physically separated critical facilities.

The proposed natural gas-fired single CHP unit will provide essential reliability to the Chateaugay microgrid. Natural gas emits significantly fewer greenhouse gases per unit of energy than diesel or fuel oil (the typical fuel sources for backup generators), and it is currently more cost-effective than combined solar and storage systems. Adding CHP capability to the generator also greatly increases the efficiency and commercial viability of the system. The CHP unit will make the energy supply in Chateaugay more resilient and will lessen the strain on the local electricity transmission and distribution (T&D network by reducing the need for power imports during peak demand events. The proposed solar array will help offset emissions from the CHP unit and represents a significant investment in local renewable energy generation.

2.2 Microgrid Required and Preferred Capabilities (Sub Tasks 1.1 and 1.2)

The NYSERDA statement of work (SOW) 65627 outlines 15 required capabilities and 18 preferred capabilities each NY Prize microgrid feasibility study must address. Table 1 summarizes required and preferred capabilities met by the proposed microgrid design in greater detail.

Table 1. Microgrid Capabilities Matrix

NYSERDA's required and preferred capabilities with annotations of whether the Chateaugay microgrid will meet these criteria.

Capability	Required/ Preferred	Microgrid will meet (Y/N)
Serves more than one, physically separated critical facilities	Required	Y
Primary generation source not totally diesel fueled	Required	Y
Provides on-site power in both grid-connected and islanded mode	Required	Y
Intentional islanding	Required	Y[1]
Seamless and automatic grid separation/restoration	Required	Y
Meets state and utility interconnection standards	Required	Y
Capable of 24/7 operation	Required	Y
Operator capable of two-way communication and control with local utility	Required	Y
Load following while maintaining the voltage and frequency when running in parallel to grid	Required	Y
Load following and maintaining system voltage when islanded	Required	Y
Diverse customer mix (residential, commercial, industrial)	Required	Y
Resiliency to wind, rain, and snow storms	Required	Y
Provide black-start capability	Required	Y
Energy efficiency (EE) upgrades	Required	Y
Cyber secure and resilient to cyber intrusion/disruption	Required	Y
Microgrid logic controllers	Preferred*	Y
Smart grid technologies	Preferred*	Y
Smart meters	Preferred	N
Distribution automation	Preferred*	Y
Energy storage	Preferred	N
Active network control system	Preferred*	Y
Demand response (DR)	Preferred	Y[2]
Clean power sources integrated	Preferred	Y
Optimal power flow (OPF) (economic dispatch of generators)	Preferred	Y
Storage optimization	Preferred	N
PV observability, controllability, and forecasting	Preferred	Y
Coordination of protection settings	Preferred	Y
Selling energy and ancillary services	Preferred	N
Data logging features	Preferred	Y
Leverage private capital	Preferred	Y
Accounting for needs and constraints of all stakeholders	Preferred	Y
Demonstrate tangible community benefit	Preferred	Y
Identify synergies with Reforming the Energy Vision	Preferred	Y
* capability is characterized as preferred by NYSERDA but is a required component in this design		

[1] While the system will be technically capable of intentional islanding, doing so would cut power flow to other customers on the included feeders and thus will not be feasible for economic purposes.
[2] The microgrid could participate in DR programs by increasing output from the CHP unit or backup diesel generators, but it will not intentionally enter island mode unless there is a forecasted disturbance or outage.

The sections that follow address how the microgrid will meet these capabilities in more detail.

2.2.1 Serving Multiple, Physically Separated Critical Facilities

At this stage of the study, the Town of Chateaugay and the Booz Allen team have identified five facilities and five groups of residential units that will be connected to the microgrid. Five of the connected loads will provide NYSERDA-defined critical services to the community in the case of an outage. See Table ES-1 for a full list of prospective facilities to be tied into the microgrid.

The proposed microgrid footprint occupies approximately 80 acres in Chateaugay. Loads will be interconnected via the existing medium-voltage NYSEG power line along Depot Street. Distributed microgrid equipment and control software will communicate over NYSEG's WAN utilizing the existing IT fiber optic backbone. Utilizing industry standard protocols, such as Distributed Network Protocol (DNP3), Open Platform Communication (OPC), Modbus, 61850, and Inter-Control Center Communications Protocol (ICCP) (IEC 60870-6) will enable the remote monitoring and control of distributed devices, regardless of manufacturer. The microgrid design is flexible and scalable to accommodate future expansion and technologies.

2.2.2 Limited Use of Diesel-Fueled Generators

The Project Team evaluated the possibility of using solar energy as the primary energy source for the Chateaugay microgrid, but solar arrays do not provide the necessary reliability during emergencies unless they are integrated with battery storage systems or some other form of backup generation. The Project Team determined that installing a new natural gas single CHP unit is the most cost-effective way to guarantee the microgrid's energy supply in island mode. As a comparatively low-emission, high reliability fuel, natural gas is an ideal source of energy for a community microgrid.

The microgrid control system (MCS) will maximize the deployment of energy from the solar array whenever it is available, and will meet remaining facility demand with electricity from the reciprocating generator. Backup diesel generators at the Fire Station and DPW complex may come on-line behind the meter to reduce their respective facilities' loads when the CHP unit and solar array cannot meet cumulative microgrid demand. However, because the CHP and solar array were sized to meet the microgrid's peak demand, the Project Team expects that use of the backup diesel generators will be limited.

2.2.3 Local Power in both Grid-Connected and Islanded Mode

The microgrid will provide on-site power in both grid-connected and islanded mode. In island mode, the MCS will optimize on-site generation to maintain stable and reliable power flow, and will be able to load follow and reduce generation by ~50% before encountering significant degradation in efficiency. The control system is also capable of automatic load shedding to maintain stability in island mode, but the microgrid can only disconnect Load Clusters 4 and 5 in real time.[3] The peak cumulative microgrid load was 3.11 MW in 2014, and proposed generation

[3] Proposed generation assets will maintain system stability and can reliably meet aggregate peak demand, so full load-shedding capability is not strictly necessary for the Chateaugay microgrid.

assets are sized so load shedding in island mode will typically not be necessary. In grid-connected mode, the microgrid will optimize the use of available assets to reduce energy costs when possible and export to the larger NYSEG grid when economic and technical conditions align.

The CHP unit will operate continuously in grid-connected mode, exporting energy to the larger NYSEG grid. The solar PV array will stay on-line throughout the year, but its output will depend on weather conditions and insolation. The CHP unit has sufficient capacity to provide all of the microgrid's electricity in island mode, guaranteeing that facilities will have a reliable source of power regardless of weather or time of day.

2.2.4 Intentional Islanding

The microgrid will intentionally switch to island mode when doing so will result in a more stable and reliable environment. Transitions to island mode will comply with New York State standardized interconnection requirements as well as local utility and building codes, which will ensure equipment and personnel safety throughout each phase of the switch.

Upon a command from the system operator, the MCS will automatically start and parallel the generation assets. Once the available power sources are synchronized with the grid (and each other), the system is ready to disconnect from the larger grid, and it will begin by opening the incoming utility line breakers. After completing the transition to island mode, the MCS must maintain system voltage and frequency between acceptable limits and adjust generator output to match aggregate load.

When the Chateaugay microgrid switches to island mode, it will disconnect all downstream non-microgrid loads that normally receive power from the Chateaugay 514 feeder. This means the microgrid will not switch to islanded mode to participate in demand response programs or to beat high electricity prices during peak demand events. Intentional island mode will only be utilized in forecasted grid outage scenarios.

2.2.5 Resynchronization to NYSEG Power

When operating in island mode, the microgrid will constantly monitor the status of the larger grid and will re-connect when conditions have stabilized. Signals from the MCS will prompt re-connection when monitored operational variables on the macrogrid satisfy predetermined conditions. The MCS will be capable of both automatic and manual re-connection using synchronization and protection equipment.

The microgrid design requires a new automated switch along Depot Street to serve as the point of common coupling (PCC) between the microgrid and NYSEG's system. The control system will trigger the opening or closing of this breaker, as appropriate, during system transitions.

2.2.6 Standardized Interconnection

The microgrid design complies with New York Public Service Commission (NYPSC) interconnection standards. Table 2 outlines the most significant state interconnection standards that apply to this microgrid project. Customers that wish to connect distributed energy resources projects to NYSEG's system must follow the same New York State Standard Interconnection Requirements (SIR) identified in Table 2. NYPSC Standardized Interconnection Requirements apply to distributed generators with less than 2 MW capacity. Although the proposed CHP unit is larger than 2 MW, generators that are close to 2 MW (approximately 2-4 MW) still usually follow NYPSC SIR. A recent proposal to modify the New York SIR to include generators up to 5 MW has not yet been approved. The proposed CHP unit will likely need to follow the normal NYS SIR, but there is a possibility that interconnection will need to follow the Federal Energy Regulatory Commission (FERC) guidelines for small generators (2-20 MW).

Table 2. New York State Interconnection Standards

New York State interconnection standards by category (common, synchronous generators, induction generators, inverters, and metering) and a description of the standard.

<table>
<tr><th>Standard Category</th><th>Description</th></tr>
<tr><td rowspan="6">Common</td><td>Generator-owner shall provide appropriate protection and control equipment, including a protective device that utilizes an automatic disconnect device to disconnect the generation in the event that the portion of the utility system that serves the generator is de-energized for any reason or for a fault in the generator-owner's system</td></tr>
<tr><td>The generator-owner's protection and control scheme shall be designed to ensure that the generation remains in operation when the frequency and voltage of the utility system is within the limits specified by the required operating ranges</td></tr>
<tr><td>The specific design of the protection, control, and grounding schemes will depend on the size and characteristics of the generator-owner's generation, as well as the generator-owner's load level, in addition to the characteristics of the particular portion of the utility's system where the generator-owner is interconnecting</td></tr>
<tr><td>The generator-owner shall have, as a minimum, an automatic disconnect device(s) sized to meet all applicable local, state, and federal codes and operated by over and under voltage and over and under frequency protection</td></tr>
<tr><td>The required operating range for the generators shall be from 88% to 110% of nominal voltage magnitude</td></tr>
<tr><td>The required operating range for the generators shall be from 59.3 hertz (Hz) to 60.5 Hz</td></tr>
<tr><td rowspan="4">Synchronous Generators</td><td>Requires synchronizing facilities, including automatic synchronizing equipment or manual synchronizing with relay supervision, voltage regulator, and power factor control</td></tr>
<tr><td>Sufficient reactive power capability shall be provided by the generator-owner to withstand normal voltage changes on the utility's system</td></tr>
<tr><td>Voltage regulator must be provided and be capable of maintaining the generator voltage under steady state conditions within plus or minus 1.5% of any set point and within an operating range of plus or minus 5% of the rated voltage of the generator</td></tr>
<tr><td>Adopt one of the following grounding methods:
• Solid grounding
• High- or low-resistance grounding
• High- or low-reactance grounding
• Ground fault neutralizer grounding</td></tr>
<tr><td>Induction Generators</td><td>May be connected and brought up to synchronous speed if it can be demonstrated that the initial voltage drop measured at the PCC is acceptable based on current inrush limits</td></tr>
<tr><td colspan="2">Source: NYS Standardized Interconnection Requirements and Application Process, NYPSC</td></tr>
</table>

2.2.7 24/7 Operation Capability

The project concept envisions a natural gas-fired generator as the microgrid's main generation source (the solar array will also contribute significantly throughout the year). The Town's existing natural gas supply line can support continuous operation of the reciprocating generator and the existing boilers at the McCadam Cheese Company.

2.2.8 Two Way Communication with Local Utility

There is currently no automation system in place which would allow communication between the microgrid operator and the existing electrical distribution network in Chateaugay. The new automation solution proposed in this report will serve as a protocol converter to send and receive all data available to the operator over NYSEG's WAN using industry standard protocols such as DNP3, OPC, Modbus, 61850, and ICCP (IEC 60870-6).

2.2.9 Voltage and Frequency Synchronism When Connected to the Grid

Microgrid controllers will automatically synchronize the frequency and voltage of all DER-generated power, which will include a rotating as well as an inverter based energy source. Synchronization is key to maintaining a stable power network. The larger grid also requires constant synchronization of energy sources, but its comparatively higher electrical and mechanical inertia filters out most fast dynamics. In contrast, the microgrid will be quite sensitive to fluctuations in load or generator output. It is therefore crucial to constantly monitor and regulate generator output against aggregate load in real time.

2.2.10 Load Following and Frequency and Voltage Stability When Islanded

The microgrid's control scheme in island mode is quite similar to that of the larger transmission system. The system maintains frequency by controlling real power generation and regulates voltage by controlling reactive power availability. To the degree that flexible loads are available, the MCS can curtail facility load—however, the Chateaugay microgrid will only be able to disconnect Load Clusters 4 and 5 in real time.

If generation matches the load plus the system losses (real and reactive), system frequency and voltage should stay within acceptable limits. Other factors, such as network topology and the distribution of generation and loads, can also affect frequency and voltage stability. The Project Team will consider these factors and develop a microgrid design that accounts for them in the next phase of the NY Prize competition. The comparatively small size of the microgrid introduces new, fast, and dynamics-related problems that will be carefully studied during the engineering design phase.

2.2.11 Diverse Customer Mix

Connected facilities have different effects on power quality and stability based on load size and economic sector. A microgrid with too many industrial or digital electronics-based loads may be less reliable because these loads can negatively affect power quality and stability. The Chateaugay microgrid will connect four municipal facilities, a commercial production facility, and five groups of residential units. No individual facility will have a significant negative impact on local power quality. The approximate load breakdown by sector for the Chateaugay microgrid is as follows:[4]

- McCadam Cheese Company – 80% of load
- Municipal Facilities – 8% of load
- Residential – 12% of load

The McCadam Cheese Company accounts for approximately 80% of the microgrid's electricity demand. Targeted energy efficiency upgrades at this facility could significantly reduce the facility's (and therefore the microgrid's) average electricity demand (see Section 2.2.14 for more details).

2.2.12 Resiliency to Weather Conditions

The Town of Chateaugay is exposed to the normal range of weather conditions that affect the Northeastern United States. Extreme weather events include, but are not limited to, torrential rain, snow, and wind that could cause falling objects and debris to disrupt electric service and damage equipment and lives. By implementing line fault notifications and deploying other sensors, microgrid owners can ensure the network is as resilient as possible to storms and other unforeseen forces of nature. The new CHP unit (the microgrid's main generation asset) will be constructed inside the McCadam Cheese Company's boiler room and will therefore be protected from extreme weather. The solar array will not produce energy during extreme weather events, but the CHP unit will be capable of maintaining power to the microgrid without supplemental power from renewable sources.

The microgrid's information technology (IT) system is primarily based on wireless communication. Each wireless unit will be housed inside a weather-proof enclosure to ensure resiliency during storms. Each distributed intelligent electronic device (IED) and DER will require a short length of physical wire to connect to the nearest network switch. Network switches will intentionally be placed near the IED or DER that they serve, which makes disruption of a wired connection extremely unlikely. In the event that an IED loses contact with the MCS, it is programmed to act on predetermined set points.

The distribution lines in Chateaugay will not be buried to provide extra resiliency to storms, wind, and falling trees. The Project Team evaluated the possibility of trenching and burying distribution lines and found the cost to be prohibitively high.

2.2.13 Black-Start Capability

The proposed CHP unit will be equipped with black-start capabilities. If the Chateaugay grid unexpectedly loses power, the MCS will initiate island mode by orchestrating the predefined black-start sequence. The CHP unit will require an auxiliary source of direct current (DC) power to start multiple times in case of failure. The generator will ramp up to 60 Hz and prepare to supply each of the microgrid loads in sequence. After the CHP unit has established a stable

[4] Estimated based on each facility's typical monthly electricity consumption from 2014.

power supply, the MCS will synchronize output from the 200 kW solar PV array and bring it on-line.

2.2.14 Energy Efficiency Upgrades

Energy efficiency is critical to the overall microgrid concept. Several facilities in Chateaugay have invested in significant EE upgrades. For example, Siemens recently performed an energy audit at the Town's municipal facilities and upgraded around 25% of surveyed equipment (heating, ventilation, and air conditioning (HVAC), building controls, lighting, sensors, etc.).

Although the Town has already reduced local energy use, there is still significant potential for EE upgrades in Chateaugay. The McCadam Cheese Company currently uses approximately 80% of microgrid electricity. The Project Team was unable to obtain information on the specific EE upgrades that could be implemented at this facility, but the Cheese Company will likely qualify for some NYSERDA and NYSEG EE programs.

The Project Team estimates the reduction potential for the five included facilities and five load groups to be approximately 100 kW. The project will leverage existing NYSEG EE programs to reduce load at existing facilities and will seek to qualify for NYSERDA funded EE programs.

2.2.15 Cyber Security

The Microgrid Management and Control System network data will be fully encrypted when stored or transmitted. Network segmentation by function, network firewalls, and continuous monitoring of data activity will protect the microgrid from cyber intrusion and disruption. Access to the microgrid management and control center will be limited to authorized personnel. Activating and analyzing security logs may provide an additional level of security. The operating system and firewall will be configured to record certain suspicious events such as failed login attempts.

Because the logic controllers (IEDs) will be located at or near loads, the distributed equipment will take the IT system to the "edge" of the network, where it may be more vulnerable to hackers. A practical tool to prevent unauthorized access into the IT network is a program called sticky media access control (MAC). Every network attached device has a media access control MAC interface that is unique to it and will never change. The sticky MAC program will monitor the unique address of the device and its designated network port, and if the device is ever disconnected, the program will disable that port and prevent an unauthorized device from entering the IT system.

2.2.16 Use of Microgrid Logic Controllers

Microprocessor-based IEDs serving as microgrid logic controllers are described below in Section 2.7.1. The role of the IED is to provide monitoring and control capabilities of the object being controlled.

2.2.17 Smart Grid Technologies

The microgrid will offer a distributed network architecture allowing smart grid technologies to connect to the grid via multiple protocols including DNP3, OPC, Modbus, 61850, ICCP (IEC 60870-6) and more as required.

2.2.18 Smart Meters

Chateaugay does not have smart meters installed throughout its coverage area. Smart meters are not required for the Chateaugay microgrid because the control sequence is performed at the feeder level.

2.2.19 Distribution Automation

The automation solution outlined in this study for Chateaugay's microgrid includes IEDs that are distributed at or near individual loads. Their role is to control the load and communicate monitored variables to the control system servers for processing, viewing, and data logging. IEDs can operate based on automated signals from the MCS or pre-programmed independent logic (in case of a loss of communication with the MCS).

2.2.20 Energy Storage

At this time, the cost of battery storage is prohibitively high for integration into the Chateaugay microgrid. In a recent study, Lazard estimated the levelized cost of batteries in microgrids to be between $319/megawatt-hour (MWh) to $1,000/MWh, depending on the application.[5] A natural gas generator that runs throughout the year can produce power at well under $100/MWh, and even diesel generators have operating costs of less than $250/MWh. Other technologies provide necessary resiliency in the Chateaugay microgrid, and battery storage units do not provide sufficient cash flows to recover capital costs.

Despite this, the MCS will be capable of fully utilizing and optimizing storage resources—including the charging and discharging cycles for peak demand shaving—in case the town reevaluates battery storage in the future. The price of battery storage technology is constantly decreasing, and by stacking different uses of energy storage (i.e., microgrid resiliency, frequency regulation, and PV integration), microgrid owners may soon be able to achieve a competitive levelized cost of storage.

2.2.21 Active Network Control System

The MCS will continuously monitor and control the microgrid in both grid-connected and islanded modes. Both monitoring and control will be decomposed into central (slow) and distributed (fast) components. A fast and reliable communication network is needed for such a hierarchical approach to be successful. All controllable components will communicate bi-directionally with the MCS via MODBUS, OPC, DNP3, TCP/IP, or other protocols as required. The communication infrastructure will be based on the existing fiber optics backbone partitioned using gigabit Ethernet switches.

[5] Lazard's Levelized Cost of Storage Analysis, Version 1.0.

2.2.22 Demand Response

The Chateaugay microgrid will not intentionally switch to island mode to participate in DR programs because doing so will disconnect all downstream loads on the Chateaugay 514 feeder. The microgrid's participation in DR programs will therefore be limited to curtailing flexible loads and ramping up generation from the CHP unit or the existing diesel generators at the Fire Station and DPW complex. The generation assets in the proposed microgrid are sized to approximately match the Town's peak demand, so the microgrid cannot guarantee that capacity will always be available. Participation in DR programs will likely be limited to voluntary participation when capacity is available—specifically, the microgrid may participate in the NYSEG Emergency Demand Response Program (EDRP).

2.2.23 Clean Power Sources Integration

The proposed energy sources—natural gas and solar energy—will provide the microgrid with reliable and relatively low-emission electricity. In the future, it may be possible to expand the footprint or generation assets to include additional clean power sources. At that time, the Project Team will consider biomass, expanded solar, battery storage, and fuel cells. More detailed methods to capture and convert energy by electric generators or inverters will be explored at a later time.

2.2.24 Optimal Power Flow

The proposed community microgrid has an average load of approximately 1,255 kW and a peak load of 3,112 kW. The Project Team expects microgrid owners will negotiate a long-term power purchase agreement with NYSEG in which proposed DERs are compensated for exporting energy to the larger grid in grid-connected mode. The structure of this power purchase agreement will influence the CHP's level of operation throughout the year. The MCS will optimize the output of generation sources at the lowest cost in an approach that includes fuel cost, maintenance, and energy cost as part of security constrained optimal power flow (SCOPF).

2.2.25 Storage Optimization

If the microgrid expands to include energy storage in the future, the storage system will require intelligent controls to work in unison with the microgrid controls. The MCS will fully utilize and optimize the storage resources by managing the charge and discharge of storage systems. Possible uses for storage include reducing peak demand, participating in New York Independent System Operator (NYISO) frequency regulation markets, shifting solar PV output to match aggregate load, and increasing system reliability by providing an energy bank.

2.2.26 PV Monitoring, Control, and Forecasting

The microgrid's PV inverters will usually operate at their maximum power point (MPP) because there is no associated operation and maintenance (O&M) cost. In some rare situations, the 200 kW solar PV array might have to reduce its output to help regulate frequency of local power flow or follow facility electricity demand in island mode. In such situations, the control is almost exclusively local with the output set point communicated by the central controller. As with other renewable energy sources, power output depends on weather and time of day.

The microgrid power management system includes high resolution solar forecasting. Solar forecasting can increase the value of integrated PV and storage systems by intelligently deploying storage to smooth the natural spikes in the daily PV output curve. However, the Chateaugay microgrid design does not include battery storage.

2.2.27 Protection Coordination

Microgrid protection strategies can be quite complex depending on the network topology and distribution of load and generation. The existing protection scheme assumes unidirectional power flow of a certain magnitude. The microgrid introduces the possibility of bidirectional power flow in both grid-connected and islanded mode, which may complicate the necessary protection strategy. In later phases of this study, the microgrid designer will perform protection studies that account for possible bidirectional power flows and low fault current detection which can occur when the microgrid is operating in island mode.

2.2.28 Selling Energy and Ancillary Services

It is unclear whether the microgrid will be permitted to back-feed power through Chateaugay's main substation into the broader NYSEG transmission system. If allowed, the microgrid will sell excess energy from the solar array and CHP unit to NYSEG.

The most lucrative NYISO ancillary service markets, such as the frequency regulation market, require participants to bid at least 1 MW of capacity. The microgrid's generation assets have an aggregate capacity of 3.7 MW, so participation in these ancillary service markets would represent at least 27% of overall generator capacity. Additionally, available generator capacity will likely be minimal because the CHP will be configured to operate continuously and sell energy to NYSEG. Other ancillary service markets, such as spinning and non-spinning reserves, do not provide competitive payments to relatively small scale generators, such as the microgrid's 3.5 MW CHP unit. The Project Team has concluded the microgrid most likely will not participate in NYISO ancillary service markets unless project owners overbuild generation assets.

Overbuilding the reciprocating generator may be an interesting option for microgrid owners. Owners could sell extra capacity into NYISO frequency regulation or ICAP (installed capacity) energy markets. Expansive discussion of these programs is outside the scope of this feasibility study, but the Project Team will consider these options in future phases of the competition.

2.2.29 Data Logging Features

The microgrid control center includes a Historian Database to maintain real-time data logs. The Historian Database displays historical trends in system conditions and process variables and can also be used for predicting future events such as system peaks with its built-in statistical analytics tool.

2.2.30 Leverage Private Capital

The microgrid project will seek to leverage private capital where possible in order to develop components of the microgrid. The Project Team is actively developing relationships with investors and project developers that have expressed interest in NY Prize. As the project concept matures, the Project Team will continue to engage these groups to better understand how private capital can be leveraged for this specific project. The Project Team currently envisions continuous operation of the proposed CHP unit and solar array and the sale of energy under a custom long-term power purchase agreement (PPA) with NYSEG. Investors will receive revenue from electricity sales to NYSEG, steam sales to the McCadam Cheese Company, and possibly from participation in ancillary service or DR programs. More detail is provided in Section 3.3.3.

2.2.31 Accounting for Needs and Constraints of Stakeholders

Developing the best possible value proposition for the community, utility, local industry, and other community stakeholders is one of this feasibility study's main objectives. The Project Team has engaged with all involved parties to understand their specific needs and constraints. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.3.

2.2.32 Demonstrate Tangible Community Benefit

The project's success and acceptance rely on its ability to provide benefits to the community. Active participation from the town government, utility, and community groups is crucial to designing a microgrid that meets the community's needs. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.3.

2.3 Distributed Energy Resources Characterization (Sub Task 2.3)

As described above, the Chateaugay microgrid design includes a new 3.5 MW CHP unit and a new 200 kW solar PV array. This section will discuss the benefits of the proposed resources and how they will meet the microgrid's objectives in greater details.

2.3.1 Existing Generation Assets

There are two existing diesel generators in Chateaugay: a 35 kW unit at the Fire Station and a 25 kW unit at the DPW complex. These assets may come on-line behind the meter in island mode to reduce their respective facilities' loads, but will not be outfitted with the necessary switchgear and controllers to respond to signals from the MCS. Because the CHP unit and solar PV array are sized to meet the microgrid's cumulative peak demand, the Project Team does not expect that the backup diesel generators will be used frequently.

2.3.2 Proposed Generation Assets

The microgrid design includes two new generation assets: a 3.5 MW natural gas-fired continuous duty reciprocating generator with CHP capability and a 200 kW PV array system, shown in Table 3. They will be located at the McCadam Cheese Company, which has land available for both DERs. The CHP system will supply 25% of the facility's annual steam demand. Existing natural gas infrastructure in Chateaugay will support continuous operation of the CHP unit.

The CHP unit will be constructed in the Cheese Company's existing boiler room, and the solar array will likely be ground-mounted on the land south of the production facility. The CHP unit will require approximately 1,500 square feet of space (56 ft. x 26 ft.). The solar array will require around 0.4 acres of land.

Table 3. Proposed Generation Assets

Table shows the rating, fuel, and address for proposed generation assets. Table also provides their labels for Figure ES-1.

Name	Technology	Rating (kW)	Fuel	Address
DER1	CHP system	3500	Natural Gas	23 Collins St
DER2	Solar PV Array	200	Sunlight	23 Collins St

2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics

The proposed design provides Chateaugay with several additional energy resources. In grid-connected mode, the microgrid's DERs will operate in parallel with the main grid, exporting electricity to the larger NYSEG grid and providing steam to the McCadam Cheese Company. In islanded mode, the MCS will first deploy energy from the solar array and then regulate output from the CHP unit to meet remaining electricity demand. The CHP unit is sized to meet the entire current microgrid load so long as several facilities do not simultaneously exceed their 2014 peak demand. In general, peak demand is typically coincident with the peak output of solar units, therefore, the combination of the CHP unit and the solar array should be sufficient to meet peak demand of the microgrid, absent significant load growth. In the event the solar array is not operating at peak demand, the existing diesel units will be available to provide support, and in times of lower demand the CHP unit will be able to reduce generation to maintain a proper level of service. In this case, the existing boilers in the McCadam Cheese facility would increase output, such that the facility could continue to be productive.

The CHP unit will be constructed inside the McCadam Cheese Company's existing boiler room, where it will be protected from severe weather events. The natural gas pipeline is buried to protect it from severe weather.

The microgrid's IT system, through which the MCS regulates generator output, is primarily based on wireless communication and is the backbone for secure communications within the microgrid. Each wireless unit will be housed inside a weather-proof enclosure to ensure resiliency during storms. Each distributed intelligent electronic device and DER will require a short length of physical wire to connect to the nearest network switch. Network switches will intentionally be placed near the IED or DER that they serve, which makes disruption of a wired connection extremely unlikely. In the event that an IED loses contact with the MCS, it is programmed to act on predetermined set points.

The distribution lines in Chateaugay will not be buried to provide extra resiliency to storms, wind, and falling trees. The Project Team evaluated the possibility of trenching and burying distribution lines and found the cost to be prohibitively high.

The proposed CHP unit will provide:

- Automatic load following capability – the generator will be able to respond to frequency fluctuations within cycles, allowing the microgrid to balance demand and supply in island mode.

- Black-start capability – the generator will have auxiliary power (batteries) for black starts and can establish island mode grid frequency. After the CHP unit has established stable power flow, the main microgrid controller will synchronize the solar array to match the CHP unit's frequency and phase.
- Conformance with New York State Interconnection Standards,[6] described in Table 2.

The New York State Public Service Commission publishes Standardized Interconnection Requirements for distributed generators that are smaller than 2 MW. Although the proposed CHP unit is larger than 2 MW, generators that are close to 2 MW (2-4 MW) still usually follow normal Standardized Interconnection Requirements (SIR). The proposed CHP unit will most likely follow the normal New York State SIR, but there is a possibility that interconnection will instead follow the Federal Energy Regulatory Commission (FERC) guidelines for small generators (2-20 MW).[7] However, the NYPSC recently proposed modifications to the SIR that would allow generators up to 5 MW to follow the normal New York State SIR.

2.4 Load Characterization (Sub Task 2.2)

The Project Team sized proposed DERs according to electricity and steam demand data from Chateaugay's load points. The load characterizations below describe the electrical loads served by the microgrid.[8] Descriptions of the load sizes to be served by the microgrid along with redundancy opportunities to account for downtime are included.

2.4.1 Electrical Load

The Project Team evaluated five primary electrical loads and five load clusters for the Chateaugay microgrid. For aggregate weekly, monthly, and yearly energy consumption as well as average and peak power demand, see Table 5. For a cumulative 24 hour load profile, see Figure 2. Typical 24 hour load profiles for each facility can be found in the Appendix.

Chateaugay's proposed community microgrid will incorporate a fire station, the local Department of Public Works complex, a water filtration and pumping plant, the local garage for emergency vehicles, and a commercial production facility. All included facilities are connected to the primary NYSEG feeder in Chateaugay (Chateaugay 514).

[6] New York State Public Service Commission. Standardized Interconnection Requirements and Application Process for New Distributed Generators 2 MW or Less Connected in Parallel with Utility Distribution Systems (2014). Available from *www.dps.ny.gov*.

[7] FERC guidelines can be found at: http://www.ferc.gov/industries/electric/indus-act/gi/small-gen.asp.

[8] Estimated loads are based on metering data from the facility's account numbers via NYSEG's on-line metering portal wherever possible. The Project Team simulated load data for the following facilities: Primary Water, Town Garage, Fire Station, and Load Clusters 1-5.

Table 4. Town of Chateaugay List of Prospective Microgrid Facilities

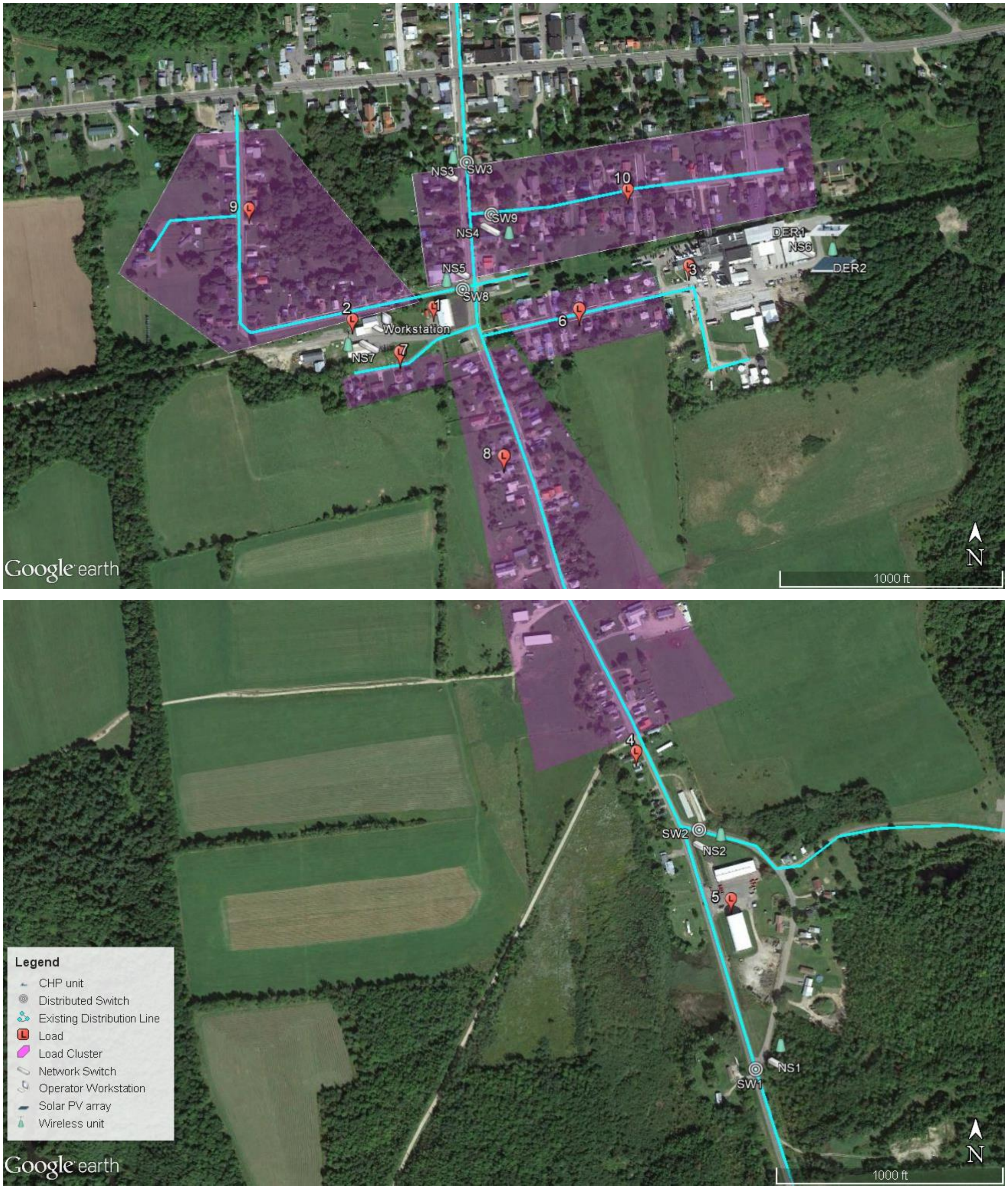
Table lists potential microgrid facilities, including their addresses, and classifications.

	Property	Address	Classification
1	**Fire Station**	2 Lake St	Public
2	**Department of Public Works, Village Office, and Storage**	10 Monroe St	Public
3	**McCadam Cheese Company**	23 Collins St	Commercial
4	**Chateaugay Town Garage**	7354 NY Route 374	Public
5	**Primary Water**	7361 Lake St	Public
6	**Load Cluster 1**	1-24 Collins St	Residential
7	**Load Cluster 2**	11-23 Iron Ave	Residential
8	**Load Cluster 3**	10-7388 Lake St	Residential
9	**Load Cluster 4**	3 Belle Ave – 6 Monroe St	Residential
10	**Load Cluster 5**	4 Monroe St – 5 Stuart Ave	Residential

The design includes several updates to existing manual switches as well as two new automated isolation switches. The Chateaugay microgrid will not require construction of new electric distribution lines. Figure 1 provides an illustration of the proposed microgrid design and layout, including loads, switches, existing electrical infrastructure, and proposed electrical infrastructure.

Figure 1. Chateaugay Equipment Layout

Figure shows the microgrid equipment layout, illustrating distributed energy resources, distribution lines, load points, servers and workstations, network switches, and proposed distribution switches.



NYSEG provided the Project Team with twelve months of metering data for the DPW complex and McCadam Cheese Company (January through December 2014), summarized in Table 5. The Project Team estimated other facility loads based on facility type, size, and approximate number of customers served. In 2014 the aggregate peak load was 3.112 MW, and the average was 1.255 MW.

Table 5. Chateaugay's 2014 Microgrid Load Points

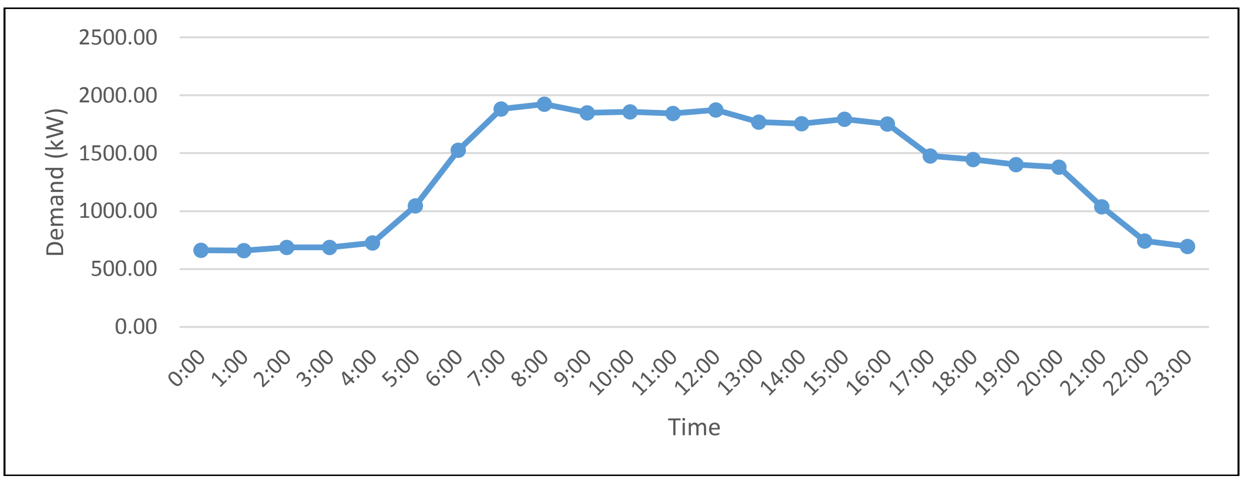
Table shows the microgrid electric demand in kW, electric consumption in kilowatt hour (kWh), and thermal consumption in MMBTU.

	Electric Demand (kW)		Electric Consumption (kWh)			Thermal Consumption (MMBTU) for Steam[9]		
	2014 Peak	2014 Average	2014 Annual	2014 Monthly Average	2014 Weekly Average	2014 Annual	2014 Monthly Average	2014 Weekly Average
Microgrid Loads	3,112	1,255	11,002,751	916,896	213,232	168,849	14,071	3,247
Post Load Shedding	2,912	1,180	10,344,001	862,000	200,465	168,849	14,071	3,247

Figure 2 provides a typical aggregate hourly load profile for Chateaugay. The daily peak demand is almost three times higher than the night-time baseline. Aggregate demand increases sharply at dawn, stays fairly level throughout the day, and decreases back to the night-time baseline from 16:00 to 22:00.

Figure 2. Typical 24-Hour Cumulative Load Profile from 2014 Metering Data

Figure illustrates the typical 24-hour cumulative load profile. The figure represents the sum of individual facility typical 24-hour load profiles from 2014.



[9] Thermal load data represents steam usage by the McCadam Cheese Company only. Other facilities did not have sufficient thermal load to merit inclusion.

The proposed 3.5 MW CHP unit will operate continuously in both grid-connected and islanded mode. Although the output of the solar array will be variable (due to weather conditions and insolation) throughout the year, the array will typically be most productive when facility demand is highest.

When the solar array is operating close to its nameplate capacity, the microgrid's generation capacity will approach 3.7 MW, with a guaranteed 3.5 MW from the CHP unit. Aggregate demand from microgrid facilities averaged 1.3 MW and never exceeded 3.1 MW in 2014.[10] The proposed DERs should therefore have adequate capacity to supply the microgrid facilities with electricity in island mode.

The Project Team expects some degree of natural load growth after construction of the microgrid. Because generators are sized to approximately match current facility demand, significant load growth could threaten the reliability of the microgrid's electricity supply in island mode. For example, the McCadam Cheese Company plans to expand their production facilities by approximately 30% in the near future (which could drive the microgrid's peak load to 3.8 MW). This expansion may necessitate a larger CHP unit or expanded solar energy production.[11] The Project Team will conduct thorough analyses of the planned facility expansion and size the DERs to match the expansion in Phase II of the NY Prize competition. Other microgrid facilities can mitigate the threat of natural load growth by investing in energy efficiency upgrades or intelligent building energy management systems (BEMS) that respond to commands from the main microgrid controller. Microgrid owners may also invest in additional supply-side resources such as small dual-fuel generators or battery storage systems.

The proposed solar array should have downtime available at various points throughout the year because the CHP will normally cover aggregate demand; however, the microgrid will need to rely on grid-supplied power if the CHP unit goes offline for maintenance.

2.4.2 Thermal Consumption

The CHP unit will provide steam for the McCadam Cheese Company. The production facility has relatively consistent steam demand throughout the year and will offtake 100% of the CHP's steam. The Project Team evaluated the thermal energy consumption of other microgrid facilities and found that none have continuous steam demand.

The McCadam Cheese Company currently uses a fleet of natural gas boilers to generate steam. Many of these boilers are approaching the end of their useful production lives, so McCadam is currently searching for a replacement source of steam. The facility uses approximately 165,000 MMBTUs of dry 122 psi steam per year. The proposed CHP unit will produce approximately 40,000 MMBTUs of steam per year, which represents around 25% of the facility's annual

[10] This number sums the individual yearly peak demands from connected facilities. It therefore assumes that all facilities reached their peak demands at the same time, which is unlikely. The true peak demand was almost certainly less than 3.112 MW, but the Project Team was unable to obtain synchronized real-time load data for all included facilities.

[11] The proposed expansion will increase the McCadam Cheese Company's thermal energy as well as electric demand, so there will should be a reliable off-taker for co-generated steam.

thermal load. Should additional electricity generation capacity be required, the McCadam Cheese Company's unserved thermal load represents an opportunity for increased production and sale of steam. Increasing the CHP unit's capacity is therefore a potential future option.

2.5 Proposed Microgrid Infrastructure and Operations (Sub Task 2.1)

The existing distribution system infrastructure will be expanded and modified to accommodate microgrid operations. The microgrid will support two fundamental modes of operation: grid-connected (normal or grid paralleling) and islanded (emergency) modes. Details concerning the infrastructure and operations of the proposed microgrid in normal and emergency situations are described below.

2.5.1 Grid Parallel Mode

The microgrid will most often operate in grid-connected mode. In this mode, the proposed 3.5 MW CHP unit and proposed 200 kW solar PV array will operate continuously, exporting electricity to the larger NYSEG grid and providing steam to the McCadam Cheese Company. Refer to Table ES-2 for a complete list of microgrid DERs.

If the larger grid experiences an emergency while the microgrid is connected, the parallel mode control scheme allows for the export of a predetermined amount of active and reactive power from microgrid DERs. By injecting power into the larger grid, the microgrid may be able to balance frequency and voltage to avert an outage.[12] If the 3.5 MW CHP unit has sufficient excess capacity, it will ramp up generation as necessary to fulfill the power requirement.

2.5.2 Intentional Islanded Mode

The proposed energy management and control scheme will balance generation with microgrid demand and maintain adequate frequency, voltage, and power flow across the microgrid network in islanded mode. Islanded mode can be intentionally used during forecasted NYSEG grid outages or disturbances to maintain electricity supply for microgrid facilities—the system will first deploy energy from the solar array and manage the CHP unit to meet remaining demand in real time. The CHP unit can provide real-time response to fluctuations in system frequency and voltage. Backup diesel generators at the Fire Station and DPW complex may come on-line behind the meter to reduce their respective facilities' load in island mode, but the MCS will not have control over these generators. Refer to the simplified one-line diagram in Figure 3 for a detailed device representation showing both existing and proposed generation assets and their utility interconnection points.

2.6 Electrical and Thermal Infrastructure Characterization (Sub Task 2.4)

This section describes the electrical and thermal infrastructure of the proposed microgrid. The infrastructure resiliency, the PCC, and the proposed utility infrastructure investment are also discussed below.

[12] By averting a larger outage, the microgrid will provide value to the community of Chateaugay as well as NYSEG. All involved parties therefore have incentive to support such a capability.

2.6.1 Electrical Infrastructure

The local utility, NYSEG, owns the existing electrical infrastructure in the Town of Chateaugay. The Chateaugay 514 line is the primary feeder in the area, and is the only feeder that supplies the Town with power. There are no redundancies in the Chateaugay electrical system.

The PCC with the NYSEG system will be located along the Chateaugay 514 feeder (SW3 in Figure 3). One new automated switch will isolate the microgrid from this feeder at the PCC. Other isolation switches will provide the microgrid with load shedding capability and disconnect downstream power lines. Three existing manual switches must be upgraded to serve their function in the microgrid control scheme—two will allow the microgrid to disconnect large groups of residential loads in island mode if aggregate demand exceeds available capacity (SW8 and SW9 in Figure 3).

The CHP and solar PV array will require switchgear and controllers to communicate with the MCS. See Figure 1 for a map of proposed equipment and infrastructure. For a detailed outline of microgrid equipment, see the one-line diagram in Figure 3.

The following tables (Table 6 to Table 8) describe the microgrid components and are referenced throughout the rest of the document. For a list of all included DERs, see Table ES-2.

Table 6. Chateaugay Distributed Switches Description

Table outlines all seven distributed electrical switches with their names (on equipment layout), descriptions, and statuses.

Name	Description	New/Upgrade
SW1	Automatic switch for feeder/load isolation	New
SW2	Automatic switch for load isolation	Upgrade
SW3	Automatic switch for feeder/load isolation	New
SW4	Automatic switch for load shedding and Microgrid sequence control	Upgrade
SW5	Automatic switch for load shedding and Microgrid sequence control	Upgrade
SW6	OEM Generator Switch	New
SW7	OEM PV Inverter Switch	New

Table 7. Chateaugay's Network Switch Description

Table outlines all seven IT network switches with their descriptions, status as existing or proposed, and addresses.

Name	Description	Status	Address
NS1	Near Switch 1 for communication	Proposed	Refer to Eqp. Layout
NS2	Near Switch 2 for communication	Proposed	Refer to Eqp. Layout
NS3	Near Switch 3 for communication	Proposed	Refer to Eqp. Layout
NS4	Near Switch 9 for communication	Proposed	Refer to Eqp. Layout
NS5	Near Switch 8 for communication	Proposed	Refer to Eqp. Layout
NS6	Near DER 1 and DER 2 for communication	Proposed	23 Collins St
NS7	For main microgrid control system and workstation for communication	Proposed	10 Monroe St

Table 8. Chateaugay's Server Description

Table describes the workstation and servers, their status as proposed, and their addresses. The Project Team has assumed that the servers will be placed inside the DPW (a secure municipal building).

Name	Description	Status	Address
Workstation	Operator/Engineer workstation	Proposed	10 Monroe St
Server1	Primary Energy Management System (EMS) and Supervisory Control and Data Acquisition (SCADA)	Proposed	10 Monroe St
Server2	Secondary EMS and SCADA	Proposed	10 Monroe St

The NYSEG distribution system in Chateaugay consists of medium-voltage lines (34.5 kilovolt (kV)). All branches off these medium-voltage lines have their own transformers that step incoming power down to low voltage.

Figure 3. Chateaugay One-Line Diagram

Figure displays a one-line diagram for Chateaugay illustrating interconnections and lay-out.

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2.6.2 Points of Interconnection and Additional Investments in Utility Infrastructure

The proposed components and interconnection points for the Chateaugay community microgrid are listed in Table 9. The PCC between the main grid and the microgrid will be located along the Chateaugay 514 feeder (SW3 in Figure 3). New automated circuit breakers and switches will be required to isolate the microgrid loads from the local NYSEG feeder and to disconnect downstream loads.

The microgrid will rely on upgrades to existing manual switches to segment loads, which will help the MCS maintain system stability in island mode. Loads 9 and 10 in Figure 3 may be disconnected in real time if aggregate demand exceeds available generation capacity. However, the proposed generation assets are sized to meet peak aggregate demand, so the Project Team does not expect that load shedding will be deployed with any regularity.

The MCS will also have precise control over generator output and can disconnect the CHP or solar PV array in real time. The CHP unit's fast ramp rate will allow the MCS to provide voltage and frequency control within the millisecond response intervals required for maintaining a stable microgrid.

Table 9. List of Components

Table lists all the distribution devices/components included in the microgrid design.

Device	Quantity	Purpose/Functionality
Microgrid Control System Protocol Converter (Siemens SICAM PAS or equivalent)	1 Primary 1 Back-up	Protocol Converter responsible for operating the microgrid's field devices via protocol IEC-61850.
Automated, Pole Mount Circuit Breaker/Switches (Siemens 7SC80 relay or equivalent)	5	New relays/controllers at pole mounted distribution switches/breakers. These components will isolate the microgrid from the local feeder and downstream loads. Two of these switches will enable load shedding in island mode.
Generation Controls (OEM CAT, Cummins, etc.)	1	OEM Generation controllers serve as the primary resource for coordinating the CHP generator's ramp up/ramp down based on external commands and reaction to Microgrid load changes.
PV Inverter Controller (OEM Fronius or equivalent)	1	Controls PV output and sends live data solar/power output data to SCADA and EMS for forecasting.
Network Switch (RuggedCom or equivalent)	7	Located at IEDs and controllers for network connection, allowing remote monitoring and control.

All microgrid devices will require a reliable source of DC power. Each device (or cluster of devices) will have a primary and backup power supply source. During normal operation, a 120 volt alternating current (VAC) power source will power an alternating current (AC)/DC converter to power the microgrid devices and maintain the charge of the DC battery banks. The device current draw (amperage used by each device) should not exceed 60% of the available power supply. When the normal AC voltage source is unavailable, the battery bank can provide DC power to devices for at least one week.

2.6.3 Basic Protection Mechanism within the Microgrid Boundary

The power protection system monitors grid variables, including voltage, current, and frequency, and takes necessary actions (such as de-energizing a circuit line) to maintain these variables at appropriate levels. Currently, protection schemes are based on the assumption that power flows in one direction. Microgrid operations, particularly during island mode, require bidirectional power flow. This will introduce difficulties for protection coordination. At a later design stage, protection studies accounting for the key characteristics of island mode will have to be performed, which include possible bidirectional power flows and very low fault currents.

The current design includes controls that can prevent back-feeding of power to the larger NYSEG grid. However, the microgrid is capable of exporting energy back to NYSEG.

2.6.4 Thermal Infrastructure

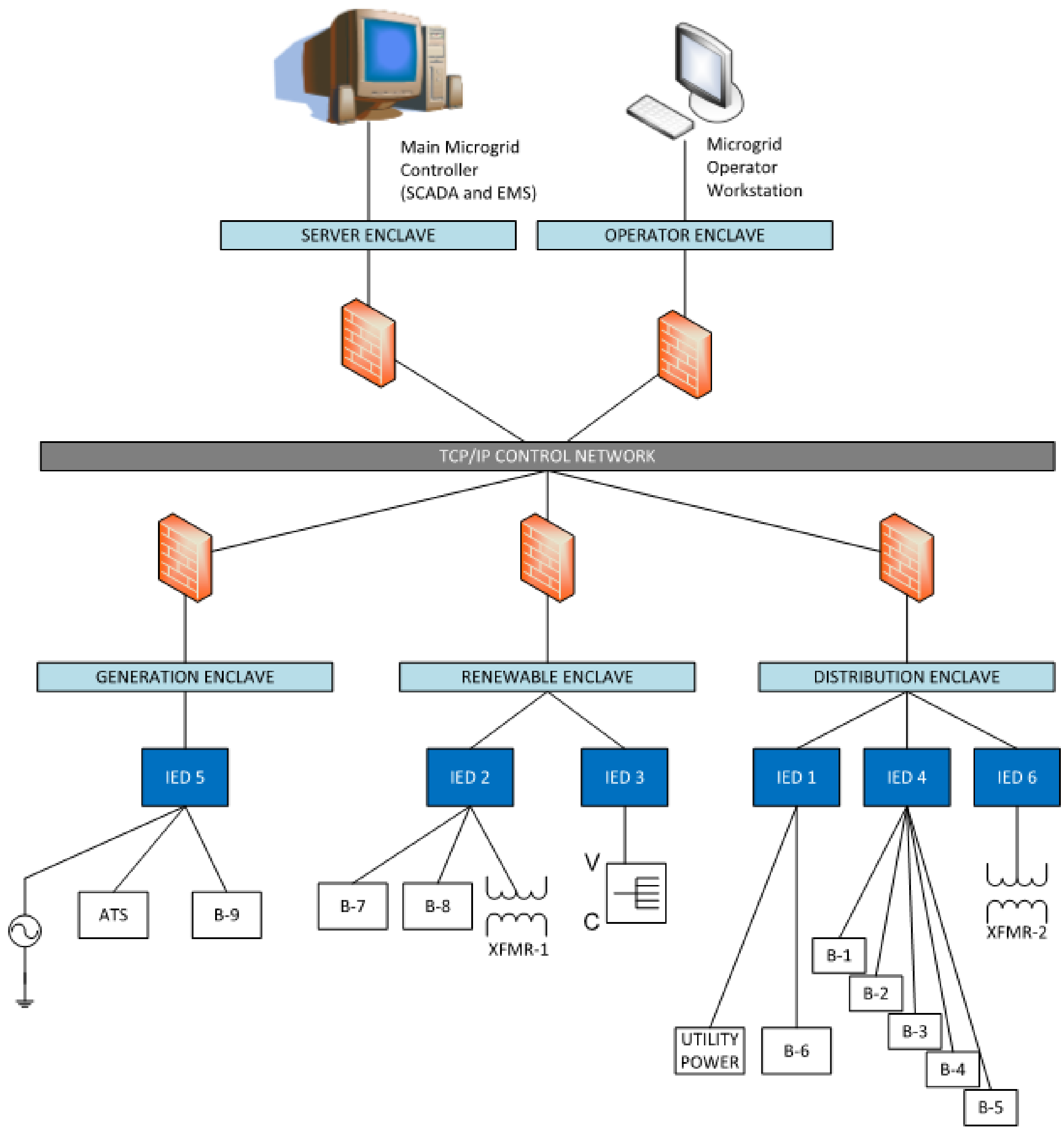
The proposed CHP unit requires a steady supply of natural gas. An existing four-inch natural gas line in Chateaugay brings a reliable supply of natural gas (15 psi) to the McCadam Cheese Company’s boilers. This line will support continuous operation of the CHP unit.

2.7 Microgrid and Building Control Characterization (Sub Task 2.5)

This section provides a more detailed description of the microgrid’s modes of operation. The microgrid control system will include an EMS and a SCADA based control center (see Figure 4), hereafter collectively referred to as the main microgrid controller. Distributed intelligent electronic devices will communicate with the main microgrid controller over the local Transmission Control Protocol/Internet Protocol (TCP/IP) network. In grid-parallel mode, the microgrid’s DERs will synchronize frequency and voltage magnitude with the larger grid and will have the potential to export excess electricity to NYSEG. When controllers detect an outage or emergency disturbance on the larger grid, the microgrid will switch to island mode. In these situations, the microgrid will disconnect from the larger grid and proceed with the programmed black-start sequence (described in Section 2.7.6) to start power flow through included lines and devices. When power returns after an outage, the main microgrid controller will manage re-synchronization to the NYSEG grid (described in Section 2.7.7).

Figure 4. Diagram of Representative Microgrid Control System Hierarchy

The following network diagram illustrates a conceptual microgrid control network with a generator, breakers, transformers, an automatic transfer switch (ATS), IEDs (which could be actuators, Meters, Accumulators, or Programmable Logic Controllers (PLCs)), a renewable energy source, and the main microgrid controller with SCADA and EMS server and client workstation node.



2.7.1 Microgrid Supporting Computer Hardware, Software, and Control Components

The following is a preliminary list of the hardware components needed for Chateaugay's microgrid:

- Energy sources – The microgrid requires DERs in order to supply electricity to connected facilities. To some degree, flexible loads that can be reduced during peak demand events may also be considered as energy sources.
- Microgrid Control System – The MCS is composed of an Energy Management System and Supervisor Control and Data Acquisition (SCADA) based control center. The MCS is responsible for logging relevant data, regulating generator output, curtailing flexible loads (where possible), and managing transitions between modes of operation.
- Distributed breakers, switches and controls – The microgrid requires automated switches and breakers to disconnect downstream loads and regulate generator output. The MCS is capable of maintaining power stability by shedding non-critical loads, such as the residential load clusters #4 and #5.
- Utility breakers and controls – These automated controls will interface between the microgrid and the NYSEG feeder on Depot St.
- New electric distribution line – A new medium-voltage express line will be necessary to connect the Fire Station and Public Works Department to the other facilities. This line will run from the Recreation Center to the Fire Station.
- Generator controls/relays – These components will be installed at each generating unit/inverter. They will control generator output based on signals from the MCS.

The proposed system uses a Service Oriented Architecture (SOA) software platform that will serve as the messaging and integration platform for the monitoring and control of distributed equipment. The SOA system supports almost any power device or control system from any major vendor and therefore ensures communication networkability and interoperability between competing vendor systems. The computer hardware and software required for a fully automated operational microgrid design are as follows:

- SOA software platform – The SOA platform facilitates the monitoring and control of included power devices and control systems.
- Two RAID 5 servers (Redundant Array of Independent Disks) (including 1 primary, 1 backup) for the MCS – The MCS will include an EMS and a SCADA based control center, and will optimize the operation of the microgrid. This includes determining which critical loads will be supplied, integrating PV output into the energy portfolio (including high resolution solar forecasting), and controlling the charge/discharge of energy storage wherever applicable. The system combines information on power quality, utilization, and capacity in real time, which allows the community and control algorithms to balance electricity supply with microgrid demand.
- Historian database server – Historian database collects and logs data from various devices on the network.

- Applications server (one or more) – Depending on the software and hardware vendors' preference, application servers may be used for numerous purposes. Common uses for an application server include backup and recovery, antivirus, security updates, databases, a web server, or use as some other software depending on how the SCADA and EMS vendors configure their platform.
- Operator workstations for SCADA and EMS – Workstation computers, sometimes called thin-clients, allow operators to view real-time data and control the microgrid from the SCADA control room or a remote location. Users must have proper access rights and permissions to operate workstation computers.
- Automated pole mount circuit breaker/switch (Siemens 7SC80 relay or equivalent) – The microprocessor based logic controllers in the field, also referred to as intelligent electronic devices, are programmed to act on predetermined set points. They can also be manually overridden by the MCS or a human operator. The control system host servers continuously poll these logic controllers for data using discrete or analog signals. Resulting data is processed by the IEDs connected to control elements. Three existing manual switches will be upgraded with these components and will disconnect downstream loads from the microgrid.
- Automated underground circuit breaker/switch (Siemens 7SJ85 relay or equivalent) – Similar to the pole mount circuit breakers, this IED can act on predetermined set points or can be controlled by an operator via the microgrid control center. This component represents an upgrade to the manual switch at the proposed PCC with the Maplewood Station 307 feeder.

Use of the listed hardware, software, and resources must be synchronized to maintain stable and reliable operation.

2.7.2 Grid Parallel Mode Control

When the microgrid operates in grid-connected mode, every on-line DER will synchronize its voltage (magnitude and angle) and frequency with the voltage (magnitude and phase) and frequency of the electrically closest interconnection point with the main grid. After initial synchronization, the generator voltage phase will drift away from the main grid's voltage phase, which will allow the flow of active and reactive power. The generator's voltage magnitude and frequency will be maintained as close as possible to the main grid's voltage magnitude and frequency. During grid parallel mode, generation assets will follow the Institute of Electrical and Electronics Engineers (IEEE) 1547 standard for interconnecting distributed resources with electric power systems. The IEEE 1547 and other DER interconnection standards required by utilities are applicable to synchronous, asynchronous, and inverter-based generation.

A utility might have additional technical and economic requirements if the microgrid plans to export energy or provide ancillary services to the distribution grid. The proposed CHP unit is capable of providing ancillary services to the NYSEG grid to enhance the reliability of the system. It can provide reactive power and frequency response services on demand, but providing reactive power support may diminish the generator's ability to generate real power.

2.7.3 Energy Management in Grid Parallel Mode

The proposed microgrid will integrate software and hardware systems to ensure reliability and effective performance. Optimization of microgrid performance involves three distinct phases: measurement and decision, scheduling and optimization, and execution and real-time optimization.

Data logging features will allow the main microgrid controller to measure historical performance and track significant trends. Human operators can use this data to prioritize loads, manage generator output, and schedule maintenance for generators and microgrid components. The microgrid executive dashboard will collect and filter information on the current operating strategy as well as performance metrics for SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index), and CAIDI (Customer Average Interruption Duration Index), all adjusted to reflect the high sampling frequency of the system. Other performance metrics include power interruptions (defined as 50% variance of predicted voltage to measured voltage for ten minutes or longer), voltage violation (defined as variance of actual voltage to predicted voltage for five minutes), and frequency violations (defined as variation to predicted frequency of more than 0.2 Hz for more than ten minutes). The executive dashboard will calculate daily, weekly, and monthly rolling totals for all of these metrics.

After analyzing historical trends and monitoring real-time data, the main microgrid controller will optimize operation of the microgrid by managing generator output and flexible loads. In grid-connected mode, the MCS will prioritize the deployment of renewable generation and will aim to offset electrical demand charges whenever possible.

2.7.4 Islanded Mode Control

The transition to island mode can be either unintentional or intentional. Unintentional islanding is essentially the main microgrid controller's programmed response to an outage at the level of the distribution or transmission system. An outage at the distribution system level can occur within or outside the microgrid, and the microgrid islanding scheme must be able to handle either situation. MCS relays at the PCC will recognize low voltage, and the appropriate switches will open automatically (disconnecting the microgrid from the larger grid). Any existing on-line generation will be isolated and ramped down via generation breakers. All microgrid loads and distribution switches will then be switched open via designated circuit breakers and relays to prepare for local generation startup. Using the CHP unit's black-start capabilities, the MCS will commence island mode operation. The generator will ramp up to 60 Hz and prepare to supply each of the microgrid loads in sequence. After the CHP unit is on-line and power flow through the microgrid is stable, the main microgrid controller will synchronize output from the solar array (voltage and frequency) and bring it on-line. In steady state, their phases will be different, just as they are during grid-connected steady state operation.

Unlike the unintentional transition to island mode, the intentional transition is seamless and closed (it does not require a black start). The microgrid will intentionally switch to island mode if:

- The NYSEG grid has an expected outage that could potentially affect transmission power to Chateaugay substations.
- The NYSEG grid needs to perform network maintenance work, thereby isolating loads in the Chateaugay area.

The intentional transition to island mode begins when the system operator sends the command to prepare for islanding. The main microgrid controller will automatically start and parallel the generation assets. Once the available power sources are synchronized, the system is considered ready to implement islanded operation and will open the incoming utility line breaker.

2.7.5 Energy Management in Islanded Mode

After completing the transition to island mode, the main microgrid controller will perform a series of operational tests to ensure the microgrid is operating as expected and that power flow is stable and reliable. The MCS will gather data on power flow, short circuit, voltage stability, and power system optimization using an N+1 (N components plus at least one independent backup component) contingency strategy to determine whether additional load can be added.[13] If additional generation is added in the future, the system has the capability for the N+1 strategy to ensure that extra generation is always online to handle the loss of the largest spinning generator and assumes the running generator with the highest capacity could go off-line unexpectedly at any time. It should be noted that low-priority loads may be disconnected in order to maintain the N+1 power assurance.

The microgrid must also be capable of handling any contingencies that may occur within the islanded system. These contingencies include:

- Generators that do not start.
- Generators that trip off unexpectedly during microgrid operation.
- Switchgear that fails to operate.
- Switchgear that fails to report status.
- Loss of power from the CHP unit.
- Loss of power from the solar array.

The MCS will optimize the microgrid's operation by managing generation assets and prioritizing critical loads according to operational requirements. Proposed DERs will provide stable, sustainable, and reliable power. The MCS will continuously balance generation and load in real-time, monitoring relevant variables (i.e., system frequency and voltage) and adjusting generator output as necessary. The main microgrid controller will first deploy energy from renewable

[13] The microgrid control system only truly has control over Loads 9 and 10 in the current design, but by installing intelligent Building Energy Management Systems or additional isolation switches, future operators of the microgrid can enhance load shedding and flexible load control capabilities.

generation assets and adjust the CHP unit's output to match remaining electricity demand. The microgrid design relies on the CHP unit's fast ramp rate to compensate for changing output from the solar array.

Battery storage is an alternative method to deal with these intermittency issues. The Booz Allen team found the cost of battery storage to be prohibitively high for Chateaugay's microgrid system. The analysis considered the potential of using storage for three purposes:

- System reliability: short-term backup, often used for voltage or frequency support or to smooth intermittent renewable ramp rates.
- Energy shifting: storing excess generation for a few hours, usually to offset higher priced periods (e.g., shifting excess solar generation from 1-3 PM to 4-6 PM when grids tend to peak).
- Longer term storage: storing energy from intermittent renewables for later use to firm up the supply to 24 hours or to improve/extend island mode operation.

The analysis indicated that storage was not needed to improve system reliability (the CHP unit's fast ramp rate provides an acceptable level of reliability). The high cost of battery storage and absence of time-of-use energy rates challenged the economics of using storage to shift generation or extend island mode operation.

2.7.6 Black Start

The proposed CHP unit will be equipped with black start capabilities. If the Chateaugay grid unexpectedly loses power, the main microgrid controller will initiate island mode by orchestrating the predefined black start sequence. The microgrid then begins the unintentional transition to island mode. A DC auxiliary support system is an essential part of the CHP unit's black start capabilities. The battery system must have enough power to start the generator multiple times in case it fails to start the first time.

When the larger grid unexpectedly loses power, the main microgrid controller orchestrates the black-start sequence as follows:

1. PCC breaker opens.
2. All active generation is disconnected.
3. The main microgrid controller waits a pre-set amount of time (approximately 30 seconds) in case power returns to the NYSEG grid.
4. The main microgrid controller disconnects the entire current load (after estimating aggregate electricity demand).
5. The microgrid DERs are synchronized with each other (one will usually provide reference voltage and frequency).
6. The main microgrid controller reconnects the microgrid loads based on the available generation and a predetermined load priority order.

The MCS will manage any contingencies that arise during the black-start operation (e.g., breakers do not respond to trip commands and the microgrid does not properly disconnect from the larger grid). The pickup loads (Load 9 and Load 10) will be energized only if sufficient capacity can be guaranteed. If the CHP unit does not start as expected during a utility outage, the MCS is equipped with contingency algorithms to appropriately manage the situation. If possible, the main microgrid controller will still isolate the microgrid, but only critical loads will be satisfied.

If more generation is added in the future, the MCS will allow operators to designate certain generators as unavailable for participation in the microgrid (e.g., if they require maintenance) so that the generator dispatch and load shedding algorithms can accommodate a reduced available capacity.

2.7.7 Resynchronization to NYSEG Power

When power is restored to the larger grid, the main microgrid controller will coordinate a safe and orderly re-connection. The system will first wait a predefined, configurable time period to ensure that power has been reliably restored and then will commence resynchronization with the NYSEG power supply. As a final check, the system operator will either receive an automated notification or directly contact NYSEG to confirm that power flow on the larger grid is on-line and stable.

While operating in island mode, the system will constantly monitor the status of the utility feeder at the PCC and determine when appropriate levels of current and voltage have been restored. When power is restored, the main microgrid controller will disconnect the solar array and synchronize output from the CHP unit with the utility service through the utility circuit breaker. Before the microgrid system starts paralleling with the utility, it will balance local generation and load so as not to exceed either minimum or maximum export limits or time durations set forth in the utility interconnection agreement. When microgrid power flow has been synchronized to the larger grid, the main microgrid controller will bring the solar array back on-line.

Please refer to the Chateaugay Microgrid Operation One-Line: Parallel Mode (from Islanded Mode) in the Appendix for the control scheme sequence of operations.

2.8 Information Technology and Telecommunications Infrastructure (Sub Task 2.6)

The existing IT and telecommunication infrastructure at Chateaugay is best suited for a wireless microgrid communication system. The communication system and network switches (which have local backup batteries) will communicate wirelessly with the base station located at the DPW complex, which is electrically served by the microgrid in islanded mode. During the intermittent stage, or Black Start sequence mode, the headend IT network equipment and base station for the IT network communications system will be powered by their backup batteries. The microgrid design will require minimal additional hardware (i.e., the network switches, WiMax Base Station, WiMax subscriber units, servers, and computers required to manage a microgrid) to seamlessly integrate with the IT system.

2.8.1 Existing IT & Telecommunications Infrastructure

Chateaugay already takes advantage of its existing fiber optic backbone ring and existing Ethernet switches for reliable Internet and Local Area Network (LAN) activities, making convergence quite feasible. The wireless components of the control system, which work on open architecture protocols, use a TCP/IP Ethernet-enabled component that controls each of the uniquely addressed modules to wirelessly communicate via a standard, non-licensed radio frequency mesh 900 megahertz (MHz) industrial scientific and medical (ISM) band signal network.

2.8.2 IT Infrastructure and Microgrid Integration

New hardware and software will be required to ensure compatibility between the existing IT infrastructure and proposed microgrid system. There are seven main components required for any microgrid system to successfully integrate with an IT/telecommunication infrastructure: host servers, application servers, operator workstations, network switches, network-attached logic controllers, data transmission systems (either fiber or Ethernet cables), and the vendor agnostic SOA software that facilitates the monitoring and control of virtually any power device or control system. All of these critical parts work together and serve a specific role.

2.8.3 Network Resiliency

Cyber security falls into the two primary stages (1) design and planning, and (2) continuous operations. Cyber security is especially important for the microgrid control system as it utilizes TCP/IP protocols for compatibility amongst the distribution system. This convergence has also introduced vulnerabilities to the MCS because the MCS vendors have historically lagged behind in implementing security patches rolled out by Windows, or PC-based security teams.

For the planning stage, design considerations address cyber security by assigning roles to network-attached components on NYSEG's WAN thereby controlling data flow and access permissions over the integrated MCS and overarching IT architecture.[14] For example, the design utilizes a network segmentation scheme by function (separate segments/enclaves for servers, operators, generation, and distribution), in addition to network firewalls, for clean and continuous monitoring and control of data flow. The firewall routes noncritical traffic such as utility's unrelated corporate printers and other drivers, email, and all other non-essential internet services (which could be backdoors for hackers into the MCS) to a dedicated "demilitarized zone" usually consisting of a single security hardened server.

Because the logic controllers will be located at or near loads, the distributed equipment will take the IT system to the "edge" of the microgrid operator's network, where it is potentially more vulnerable to hackers. Sticky media access control (MAC) is an inexpensive and practical program that can help prevent unauthorized access and protect the operator's IT network. Every network attached device has a unique, unchanging MAC interface. The Sticky MAC program is configured to monitor the unique address of the device and its designated network port. If the

[14] Assumes the microgrid will utilize enterprise-level remote monitoring and control.

device disconnects, the program disables the port and thus prevents an unauthorized device that may have malicious code from entering the IT system.[15]

Physical security measures, such as electronic badge access or cipher combination hardware locksets, should also be considered. The Project Team recommends implementing physical security at the perimeter of the control center building and network communication closets where the switches reside.

The data transmitted throughout the proposed Chateaugay microgrid will be encrypted, but several additional intrusion protection measures can easily be implemented. One simple and inexpensive method is to disable any of the 65,535 TCP ports not used to make the microgrid system work (depending on final configuration, only a few TCP ports will need to be active). More TCP ports will need to be active when the available enterprise-level monitoring and control access will be utilized.

Activating and analyzing security logs is also important. As a rule, the operating system and firewall can be configured so certain events (e.g., failed login attempts) are recorded. The security portion (software that resides on the control system servers) will be configured so only operators and engineers with specific login credentials can access and control the microgrid.

In the event of a loss of communication with the IT system, the microgrid will continue to operate. The programmed logic code for the network attached controllers is stored locally in each module, giving the controllers the ability to operate as standalone computers in the event of a disruption between the IT system and microgrid.

Cyber Security will also be considered during the operations stage to maintain against ongoing threats. Although MCS vendors in the past use to perform only minimal software regression tests for bugs; in recent years, the MCS vendors have been working on these issues continuously to mitigate security risks. It is important to note the proposed MCS network attached components can be upgraded online as software updates become available. The MCS could be upgraded automatically whenever an update is available or manually after testing the updates in a non-production environment. In either case, a networked server is used to deliver the updates. Each approach has its own benefits and drawbacks. Automatic upgrading installs updates as soon as they are available but they might not function as expected in the given environment. Upgrading manually allows for testing to ensure correct functioning but the upgrades might be delayed over automatic upgrades. In either case, a networked server is used to deliver the updates.

It is strongly recommended these updates be tested or simulated first in a non-production environment. The simulated model is easy to mimic with artificial (input/output) I/O points. Any reputable control systems programmer/integrator does such testing before the commissioning stage; the same I/O model and hardware configuration could be used for the security update tests in the future. The Team considers the safety and availability of the microgrid to be the most

[15] Sticky MAC is a common, widely effective IT security countermeasure. The Project Team does not foresee any difficulties integrating Sticky MAC into microgrid operations.

critical aspects of the microgrid. Testing and/or simulation of the system responses to software updates is important because it allows the owner or operator to identify any anomalies which the software updates might introduce to the overall system before full deployment in the field. Further considerations will be assessed during the next phase of the Prize initiative.

2.9 Microgrid Capability and Technical Design and Characterization Conclusions

After thorough examination of existing utility infrastructure and energy demand requirements, the Project Team has provided a reliable microgrid design. Control components will efficiently manage the real-time operation of the microgrid by communicating with distributed IEDs. The proposed design is resilient to forces of nature and cyber threats and offers full automation and scalability at every level. The SOA-based framework ensures interoperability and compatibility between components, regardless of final vendor.

In conclusion, the project is feasible. However, two significant items remain in order for Chateaugay's microgrid to become a reality. First, generation assets and microgrid components must be available for maintenance at all times. The team is working with the facilities to ensure that they will allow a third party to service the generation assets and microgrid components located on their land. The Project Team expects these operational challenges to be resolved by the time of construction. Second, the microgrid design must account for the McCadam Cheese Company's planned expansion of production facilities. The current design sizes generators to current microgrid load, but if the Cheese Company expands production by 30%, there may be a corresponding increase in electrical and thermal demand. Future phases of the NY Prize competition will include thorough analyses of the planned expansion and required DER size to match aggregate microgrid demand.

The microgrid design proposes upgrades to five existing manual switches and installation of four new automated switches. Existing natural gas and thermal infrastructure in the Town will support continuous operation of the CHP unit, and investments in steam infrastructure to carry steam from the CHP unit to McCadam production facilities should be minimal.

3. Assessment of Microgrid's Commercial and Financial Feasibility (Task 3)

The conclusions in this document are predicated on several fundamental assumptions:

- Private investors will own the DERs and the control and distribution infrastructure. It is possible NYSEG may choose to own the control and distribution infrastructure on their distribution system, if so system ownership will be a hybrid model that provides benefits to both NYSEG and the SPV.
- The CHP unit and solar array will sell electricity to NYSEG at the average local supply charge (the price NYSEG currently pays to purchase electricity, excluding transmission,

distribution, and capacity charges). The McCadam Cheese Company will purchase steam from the CHP unit.

- NYSEG, as the local expert in energy distribution and the current owner and operator of the Town's distribution infrastructure, will either operate the microgrid or support a third party operator. It is not necessary for NYSEG to operate the system however, NYSEG's existing infrastructure is used extensively in the preliminary microgrid design, so operational support from the utility is vital to the project's success.
- The current regulatory, legal, and policy environment will stay consistent. The proposal outlined in this report falls within the existing frameworks.

The Chateaugay microgrid will produce competitive returns for investors. Cash-based value streams will accrue to members of the SPV. Combined, the new generation assets will produce revenues of approximately $1.7 million per year. This includes approximately $1.58 million in electricity sales from the CHP, $15,000 in electricity sales from the solar array, and $110,000 in thermal energy sales from the CHP. Normal operation will produce an operating profit of approximately $540,000 per year, which will recover investment costs and produce positive returns. This figure includes incentives from the NYSERDA CHP Performance Program, NY Sun Program, and Federal ITC but no subsidies from the NY Prize program. With NY Prize funding, the Chateaugay microgrid project would become an attractive investment.

3.1 Commercial Viability – Customers (Sub Task 3.1)

All five facilities provide critical services (as defined by NYSERDA) to the Town during emergency situations. The project will affect several groups of stakeholders in the Chateaugay community that are not physically connected to the microgrid—the benefits and challenges to these stakeholders are discussed further in this section.

3.1.1 Microgrid Customers

The Chateaugay microgrid includes five critical facilities and five residential load clusters (see Table 1 for a list of direct microgrid customers). These customers will continue to purchase electricity from NYSEG throughout the vast majority of the year. However, when there is an outage on the larger NYSEG system, the microgrid will switch to island mode and customers will purchase electricity directly from the microgrid SPV via NYSEG infrastructure. The transition to islanded operation may be intentional or unintentional.

Although facilities outside the microgrid's footprint will not receive electricity from the microgrid's generation assets during emergency outages, local citizens will benefit from the availability of critical and important services. In their day-to-day operations, each of the critical microgrid facilities serves the larger community. By providing services to the community, these facilities extend their reach beyond direct employees and residents in the event of emergencies.

Table 10 (below) identifies each of the direct microgrid customers. The full group of stakeholders that will benefit from the microgrid is discussed in Section 3.2.3.

Table 10. Microgrid Customers

Facilities that will be connected to the microgrid. All will purchase electricity from the microgrid in island mode, and will indirectly purchase electricity from the microgrid's DERs in grid-connected mode.

Property	Address	Classification	Critical Service	Back-up Generation
Fire Station	2 Lake St	Public	Yes	Yes
Department of Public Works, Village Office, and Storage	10 Monroe St	Public	Yes	Yes
McCadam Cheese Company	23 Collins St	Commercial	Yes	No
Chateaugay Town Garage	7354 NY Rt 374	Public	Yes	No
Primary Water	7361 Lake St	Public	Yes	No
Load Cluster 1	1-24 Collins St	Residential	No	No
Load Cluster 2	11-23 Iron Ave	Residential	No	No
Load Cluster 3	10-7388 Lake St	Residential	No	No
Load Cluster 4	3 Belle Ave – 6 Monroe St	Residential	No	No
Load Cluster 5	4 Monroe St – 5 Stuart Ave	Residential	No	No

3.1.2 Benefits and Costs to Other Stakeholders

Stakeholders in the Chateaugay microgrid extend beyond connected facilities to include SPV investors, existing generation asset owners, NYSEG, and residents of Chateaugay and the surrounding communities.

The majority of benefits and costs to stakeholders fall into the following categories:

- Supply of power during emergency outages
- Maintenance of local emergency services and economic activity
- Electricity generation in grid-connected mode
- Thermal energy generation in grid-connected mode
- Cash flows to owners
- Upfront capital investment and land requirements

Details of each will be discussed in turn below.

Supply of power during emergency outages: The microgrid will supply power to five critical facilities as well as five residential load clusters. The critical facilities can provide economic activity, emergency services, and local government services to residents of the Town in the event of a long-term grid outage.

Electricity generation in grid-connected mode: The new 3.5 MW CHP and 200 kW solar array will operate continuously in grid-connected mode, selling electricity to NYSEG under a custom long-term PPA. Continuous energy generation will reduce load for the larger NYSEG system during both peak demand events and normal periods of operation, stabilizing electricity prices in the area and possibly deferring the utility's future capacity investments. Although

Chateaugay is not considered a congestion point on the larger NYSEG and NYISO systems it is adjacent to the congested load pocket in Clinton County and peak load support from proposed generation assets will reduce regional congestion costs to NYISO, NYSEG, and their electricity customers.

Thermal energy generation in grid-connected mode: The CHP unit will provide steam to the McCadam Cheese Company throughout the year. Co-generated thermal energy will provide around 25% of the cheese company's steam demand, replacing an existing natural gas-fired boiler. The cheese company will benefit from reduced O&M costs associated with this boiler.

The McCadam Cheese Company plans to expand its production facilities over the next five years. This expansion will drive a 30% increase in demand for electricity and thermal energy. Depending on the final date of project construction, SPV owners may wish to scale the CHP unit up to 5 MW. However, the 3.5 MW CHP unit is sized to approximately meet the cheese company's current lowest average thermal energy demand point, which occurs in the middle of every day. Sizing the CHP unit to the lowest average thermal energy demand point makes the best use of capital investment, as preemptive expansion of the CHP unit could result in significant waste of thermal energy, and thus harm the financial returns of the project. However, McCadam may wish to proactively make this investment in order to reduce capital expenditures related to their expansion in the future.

Cash flows to DER owners: Cash flows will be limited to electricity sales to NYSEG and thermal energy sales to the McCadam Cheese Company. The microgrid project will produce consistently positive operating cash flows, which will recover investment costs and produce positive returns. The project depends on the Federal ITC, the NY Sun Program, and the NYSERDA CHP Performance Program which is currently set to expire in 2016. This study assumes these programs, or similar programs, will be extended into 2017. Additional subsidies from NY Prize would make the Chateaugay microgrid an extremely attractive investment.

Upfront capital investment and land requirements: The primary costs will be purchasing and installing necessary microgrid equipment and proposed generation assets. The McCadam Cheese Company has extensive land available for the 200 kW solar array. The CHP will be located on the northwest side of the cheese company's production facility. The Project Team has discussed the project extensively with McCadam and the company supports hosting the proposed CHP unit.

3.1.3 Purchasing Relationship

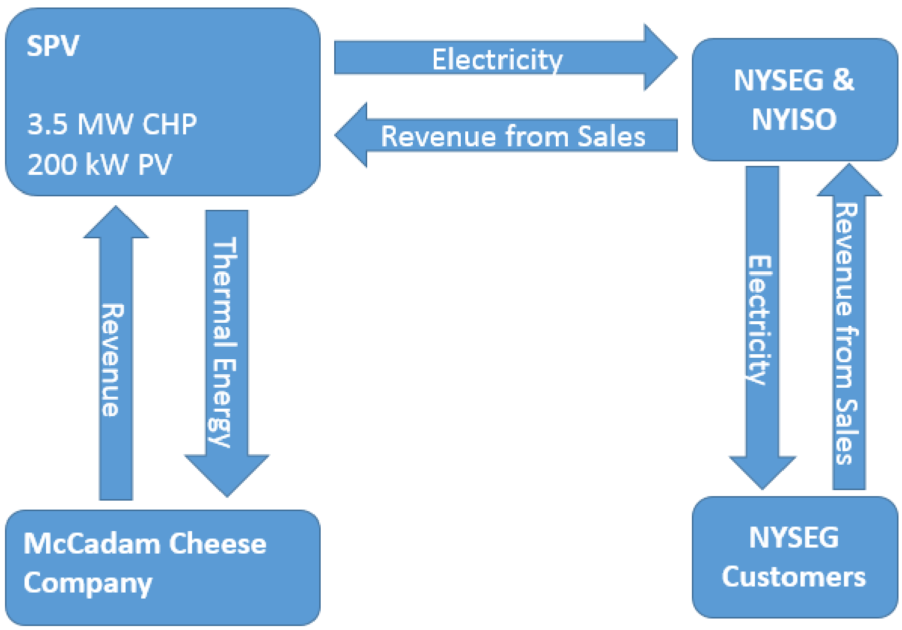
In grid-connected mode, the SPV will sell all electricity generated from the proposed CHP unit and 200 kW solar array to NYSEG under a long-term PPA.[16] Microgrid connected facilities will maintain their current electricity-purchaser relationship with NYSEG during grid-connected mode. In island mode, however, the facilities will be physically disconnected from the larger grid

[16] The proposed solar array will not qualify for net metering because it will be owned by the SPV, which does not own a metered facility in the area.

and directly supplied by the proposed generation assets. NYSEG will continue to bill microgrid facilities as normal, and proposed DERs will continue to sell electricity to NYSEG under the established long-term PPA. However, the CHP unit will be configured to follow the microgrid's electrical load in island mode rather than operating at full capacity. Islanded operation contracts will be established during development and construction, and will address both the order in which islanded facilities are brought back on-line following an island event and the associated cost for participating in the microgrid. See Figure 5 below for the purchasing relationships.

Figure 5. Purchasing Relationship

Value streams and purchasing relationships between the various entities in both grid-connected and island mode.



3.1.4 Solicitation and Registration

The microgrid design team will work with the Town and utility to formalize agreements with the identified microgrid customers. This outreach will include informal discussions and, ultimately, signed agreements of participation in the microgrid and any fee structure determined by the NYPSC. Formal registration with the microgrid will include programming the logic controllers to include or exclude facilities from islanded services based on their agreements with the utility. The Project Team views registration as an operational feature and not a legal requirement.

3.1.5 Energy Commodities

Proposed generation assets include a 3.5 MW CHP unit and a 200 kW solar PV array. During normal operation, electricity from these assets will be sold to NYSEG and distributed on the NYSEG system as dictated by system needs. Conversely, if NYSEG wishes to prevent energy from flowing to the grid, the generation assets will be equipped with controls that have the necessary hardware and protection scheme to prevent back-feeding power into the system. The SPV will sell steam to the McCadam Cheese Company throughout the year.

The volume of electricity purchased from the CHP will depend on the generator's output as dictated by the microgrid controllers, system demand, and agreements between the SPV and NYSEG. It will likely operate at nearly full capacity throughout the year in order to maintain a steady supply of thermal energy to the cheese company. The CHP will not participate in NYISO ancillary service markets because most lucrative markets require at least 1 MW of available capacity, which represents around 29% of the CHP unit's nameplate capacity. The requisite fast changes in output would also make the CHP unit's thermal output unpredictable, which would discourage the cheese company from purchasing co-generated thermal energy. Ancillary service markets that do not have minimum capacity requirements, such as spinning and non-spinning reserves, rarely offer competitive payments. As such, it is unlikely the project will be able to take advantage of any revenue from ancillary services.

3.2 Commercial Viability – Value Proposition (Sub Task 3.2)

The microgrid will provide value to Chateaugay, private investors, NYSEG, direct participants, and the larger State of New York. The new 200 kW solar array and 3.5 MW CHP unit will produce reliable, relatively low-emission electricity in both normal and islanded operation. SPV members will receive stable cash flows from operation of the proposed energy generation resources for the life of the project. The benefits, costs, and total value of the microgrid project are discussed in detail below.

3.2.1 Business Model

An SPV will own the proposed DERs and microgrid infrastructure and operate the system unless NYSEG requires ownership of the hardware on their system or has a preference to operate the microgrid. In grid-connected mode, the SPV will sell all electricity generated to NYSEG and thermal energy to the McCadam Cheese Company. In islanded mode, electricity will flow directly to microgrid facilities, but NYSEG will continue to bill facilities for electricity usage and pay the SPV for electricity from the DERs. The SPV will continue to sell thermal energy directly to the McCadam Cheese Company in island mode. This project configuration and business model is proposed in order to maximize the efficiency of the CHP unit and the potential of financial partners being willing to put equity capital into the project by reducing their financial risk. Since CHP units operate most efficiently when running at a steady load, it is operationally advantageous to size the unit based on either a baseload electricity level or baseload steam output. In this case the CHP unit has been sized in order to provide the minimum steam load for McCadam, which equates to approximately 25% of the facility's overall steam load.

Sizing the CHP unit in this manner has two direct benefits from the perspective of private capital. First, this allows for 100% of the electricity to be sold to the local utility on a long term PPA, which also allows the investor to avoid the "merchant risk" of selling into the NYISO markets. Additionally, in conversations with investors the project team recognized that a long term PPA to the distribution utility creates a lower risk profile for the project, as the utility typically has a better credit rating than an industrial user, and selling the two commodities from the CHP unit to two different counterparties creates a more diverse revenue stream for the project. In whole, this structure creates a business model that leverages the utility's credit rating and provides diverse income streams, which makes the investment require a lower internal rate of return target and makes an easier decision for the finance partners' investment committee. SPV members will then receive shares of operating cash flow that correspond to their initial investments, and investors will determine the most appropriate financing mix to achieve their financial goals. If NYSEG is responsible for the installation, ownership, and operation of the non-revenue generating controls infrastructure the SPV will remit payment to NYSEG to offset these costs.

Table 11 below provides an overview of the Chateaugay microgrid project, including an analysis of project strengths, weaknesses, opportunities, and threats (SWOT).

Table 11. Chateaugay Microgrid SWOT Analysis

The strengths, weaknesses, opportunities, and threats (SWOT) associated with the Chateaugay microgrid project.

Strengths	Weaknesses
• Allows for the use of existing T&D infrastructure, thereby reducing the potential cost burden of constructing new lines and feeders (microgrid project will only require isolation switches to disconnect the microgrid from the feeder and downstream loads) • Co-generated thermal energy will provide an additional revenue stream to the SPV and replace an existing boiler (or multiple boilers) at the cheese company • Engages key critical facilities as well as local residents and businesses • Leverages revenue generating assets to cover the capital costs associated with the non-revenue generating hardware, software and controls • Selling electricity at NYSEG's supply price and thermal energy at a competitive local rate will recover the project's investment costs and provide positive returns to investors	• NYSEG has not committed to any stake in ownership or operations of the microgrid at this time
Opportunities	**Threats**
• Encourages teamwork between local government, private investors, and local investor owned utility. Because most communities are served by IOUs, this model could serve as a template for future projects • Demonstrates the feasibility of reducing load on the larger grid with distributed energy resources • Provides a proof point for utility operated microgrids in partnership with a private DER investor group • Capturing additional subsidies such as NY Prize Phase III funding could make the Chateaugay microgrid a highly attractive investment	• Changes in regulatory requirements could impact the proposed business model and stakeholder goals. • If natural gas prices increase, it will significantly raise the microgrid's marginal cost of producing electricity, which may prompt a re-negotiation of NYSEG's purchasing price • Commercial feasibility relies on subsidies such as the NYSERDA CHP Performance Program, which may not be available several years in the future

Although there are several valuable strengths and opportunities associated with the hybrid ownership model, there are also weaknesses and threats that must be addressed and, if possible, mitigated.

- **Financial** – First, SPV members will seek a long-term PPA, or some other form of long-term purchase agreement, with NYSEG to guarantee steady future revenue streams. As long as the agreement reliably guarantees fair compensation for generator output over the project lifespan, SPV members must be content with flexible compensation rates and a low amount of risk. Second, the project's commercial viability depends on subsidies such as the NYSERDA CHP Performance Program and the NY Sun Program. These programs may not be available several years in the future. To mitigate this threat, the Project Team recommends beginning planning and design as soon as possible.
- **Organizational Competition** – This business model requires collaboration among groups of stakeholders that may have different motivations for participation in the microgrid project. With NYSEG's role still undefined the Project Team has made operational and ownership assumptions that may change in Phase II as the utility develops more clarity around their goals and requirements with regard to microgrids within their service territory. Open communication and early agreement between NYSEG and private investors regarding operational parameters, volumes of electricity to be purchased, ownership of the hardware and controls, and the price per unit of electricity will be paramount for the smooth operation of the microgrid.

3.2.2 Replicability and Scalability

The Chateaugay microgrid is a largely replicable and scalable model, and it is being designed with industry standard equipment and software that can be applied to diverse existing infrastructure.

Technical Replicability. The proposed microgrid technology does not present a barrier to project replicability. The primary components of the microgrid, including the proposed generation assets, switches, SCADA, and the EMS, are widely available and could be repeated in any given location. All interconnections with the NYSEG grid are industry standard. Natural gas infrastructure is an essential component of the project's replicability; without a steady natural gas supply, other communities would have to sacrifice the reliability (by relying on solar and/or wind power) or emissions efficiency (by using diesel or fuel oil) that make this project feasible.

Organizational Replicability. Because most municipalities in NYS follow a similar electricity model in which the local IOU distributes power purchased from third-party owned generation assets, the project's power distribution structure is easily replicable. Private DER ownership coupled with utility infrastructure ownership is both replicable and desirable as it brings private capital into the energy arena and provides a platform for utilities to realize revenue from the projects. In the event NYSEG prefers to operate the system, IOU full operational control over the generation assets without any financial stake in them is not one that has been widely implemented. It is the opinion of the Project Team, however, the proposed model provides a path ahead for grid-integrated microgrids in a fashion that engages utilities, which may otherwise be skeptical of their value proposition.

The proposed generation assets qualify for significant incentive payments—the NY Sun program will offset around 30% of the solar array's capital cost, the Federal ITC will offset an additional 30% of the solar array's capital cost, and the NYSERDA CHP Performance Program will recover around $2 million of the CHP's capital cost in the project's first three years. These incentives are essential to the project's commercial viability. Termination or expiration of any of these programs could hinder the replicability of this design in the future.

Scalability. The Chateaugay microgrid is scalable on the Chateaugay 514 feeder, but expansion would require new isolation switches and additional generation. The CHP unit is sized to meet the cheese company's lowest thermal energy demand point. Additional generation would therefore need to take the form of natural gas reciprocating engines without CHP capability or paired solar and storage systems.

Expanding the microgrid on the Chateaugay 514 feeder would also require additional power studies and analyses.

3.2.3 Benefits, Costs, and Value

The microgrid will provide widely distributed benefits, both direct and indirect, to a multitude of stakeholders. The SPV will receive stable cash flows for the lifetime of the project, the Town and citizens will benefit from a more resilient electricity system, and the community will reap the positive effects of living in and around the microgrid during times of emergency. These costs and benefits are described in Tables 12 through 17. Moreover, the local community will not bear any of the project's costs. This proposal involves a wide group of stakeholders—from local, non-customer residents to the State of New York—and provides value to all involved parties. Tables 12 through 17 below provide an overview of the benefits and costs to members of the SPV, direct microgrid customers, citizens of Chateaugay and surrounding municipalities, and the State of New York.

Table 12. Benefits, Costs, and Value Proposition to SPV

SPV shareholders will receive stable cash flows from the microgrid project for the lifetime of the project.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
SPV	- Investors will receive annual cash flows from electricity sales, thermal energy sales, and microgrid connection or participation fees - Federal ITC and NY Sun incentive together recover around 60% of solar array's cost in the project's first year - CHP Performance Program pays around $2 MM in the project's first three years - NY Prize Phase III funding would recover an additional 50% of capital costs	- Initial capital outlay for generation assets - Forecasted installed capital costs for the solar array and CHP unit are $480,000 and $7 MM, respectively - Ongoing operations and maintenance of DERs - Financing costs associated with initial capital outlay will persist for many years	- Low risk returns assured through long-term purchase contracts make the proposed DERs an attractive investment - With existing subsidies and projected cash flows from normal operation, SPV shareholders will receive a competitive return on investment

Table 13. Benefits, Costs, and Value Proposition to NYSEG

NYSEG will receive new revenues from the operation of the microgrid while bearing only a fraction of initial and ongoing costs.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
NYSEG	- The utility will continue to sell electricity to direct customers - NYSEG will maintain full control of distribution lines and new control infrastructure - The utility may realize cost savings on decreased line congestion - Local generation reduces the amount of power that must be imported from the larger grid - Improved reliability provided to customers within the microgrid footprint	- NYSEG will purchase electricity from the CHP and solar array at a price consistent with its existing electricity supply costs - If NYSEG elects to own the hardware and controls, NYSEG will bear the cost of installing and maintaining the microgrid control infrastructure	- The utility can serve as a market connector, realizing revenue from T&D and fees from the DERs - Improved grid resiliency by integrating local generation assets with local distribution networks - NYSEG will have a new supply of electricity valued at their average supply charge but will marginally reduce their T&D costs in the immediate area

Table 14. Benefits, Costs, and Value Proposition to the Town of Chateaugay

The Town of Chateaugay will become a leader in achieving NY REV goals by providing a local market for DER-generated electricity and catalyzing investment in DER assets.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Town of Chateaugay	- The microgrid will provide a resilient and redundant energy supply to critical services that are available to the whole Town - Meet NY Reforming the Energy Vision goals by encouraging DER construction and improving energy resiliency - Expand local renewable energy generation - Approximately 16% of households in Chateaugay are included in the microgrid, with the potential to expand coverage in the future	- When the microgrid enters island mode due to a larger grid outage, customers may pay a slightly higher price for electricity than they would for electricity from the larger grid. This cost is offset by enhanced reliability and power quality	- Critical and important services will maintain power during outages, allowing the Town of Chateaugay to serve as a relief point for the local community - The microgrid project will serve as a catalyst for customers becoming more engaged in energy service opportunities and will inspire residential investment in DER assets, such as solar PV and battery storage, as citizens see benefits associated with avoiding peak demand hours, producing enough electricity to be independent from the larger grid, and selling electricity in a local market - Generating electricity with the new solar PV array and an efficient CHP unit will offset emissions from potential diesel backup generation

Table 15. Benefits, Costs, and Value Proposition to Connected Facilities

Connected facilities will benefit from a more resilient energy supply and may choose to invest in small DER assets of their own.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Connected Facilities	- Resilient and redundant energy supply to operations - Access to a local market for distributed energy resources makes investments in small DERs more attractive to connected facilities - Thermal energy from the CHP unit will reduce the need for existing boilers at McCadam Cheese	- Potential for slightly higher electricity prices during island mode, depending on the outcome of PPA contract negotiations in NY Prize Phase II	- Maintain operations during emergency outages and provide valuable critical services to the Chateaugay community - Potential for partnerships and a local market for excess generation will encourage industrial stakeholders to build large-scale generation assets - Local market for excess energy makes investments in small DERs (such as solar panels) profitable for connected facilities - The McCadam Cheese Company will reduce operation and maintenance costs associated with generating thermal energy

Table 16. Benefits, Costs, and Value Proposition to the Larger Community

The larger community will have access to critical services and may have some ability to reconnect power (if the microgrid expands connections in the future) during grid outages.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Community at Large	- Access to a wide range of critical and important services during grid outages	- Because the larger community will not be connected to the microgrid, this stakeholder group will not bear any costs	- Potential for reconnect in outage situations if generation assets are out-producing the connected critical loads and the footprint of the microgrid is expanded - Future expansion of the microgrid could bring more facilities into the design—however, the Town of Chateaugay will likely need to install advanced metering infrastructure (AMI) meters for this to be feasible

Table 17. Benefits, Costs, and Value Proposition to New York State

The microgrid provides a tangible example of a Town working towards a significant NY REV goal: to expand the privately-owned DER industry by providing a local, utility-owned power distribution platform.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
New York State	- Efficient natural gas-fired CHP unit will offset high-emission peaking assets during peak demand events - Cash flows will provide tangible evidence of microgrid project's commercial viability - Indirect benefits (such as outages averted) will demonstrate the benefits of microgrids paired with DER assets to citizens across the state and reduce load on the larger grid - Each microgrid accelerates NY state's transition from old macrogrid technology to newer, smarter, smaller technologies - Meet NY Reforming the Energy Vision goals by encouraging DER construction and improving energy resiliency	- Depending on financing plans, growth of microgrid popularity, and increased use of natural gas-fired generators, the state may need to develop additional plans for expanding natural gas infrastructure	- Successful construction and operation of a community microgrid will demonstrate the tangible value of microgrid projects - Indirect benefits associated with microgrids will encourage and inspire citizens to strive for DER in their own communities - Success of SPV model aligns with REV goals—this project provides a successful example of investor-owned generation assets selling electricity over a utility-owned power distribution platform

3.2.4 Demonstration of State Policy

The proposed microgrid represents a major step towards achieving New York State energy goals; it will provide a local platform for excess energy generation throughout the year, help the community adapt to climate change, and expand renewable energy in the Town. The proposed microgrid supports the New York State Energy Plan by providing a power distribution platform for locally-owned DER assets.

By coordinating the microgrid as a local distributed system platform (DSP), the Chateaugay microgrid will act as a distributed resource and will provide local grid stabilization through injections and withdrawals of power. As more distributed resources are added throughout the Town, the microgrid can be tuned to provide continual support for these assets (e.g., by providing ancillary services) and will diversify and enhance its portfolio of revenue streams. Eventually, as more microgrids arise in New York State, the proposed microgrid can integrate seamlessly into a larger “grid of grids” to promote energy markets, trading, and enhanced consumer choice for preferred power source.

3.3 Commercial Viability – Project Team (Sub Task 3.3)

The Project Team includes NYSEG, the Town of Chateaugay government, Booz Allen Hamilton, Siemens AG, and Power Analytics. It may expand to include financiers as the project develops. Details on the Project Team can be found in this section.

3.3.1 Stakeholder Engagement

The Project Team has been engaged in constant communication with local stakeholders from the outset. Booz Allen and its Town partners have also communicated with each of the proposed facilities to gauge electric and steam demand and discuss other aspects of the project development. Representatives from Chateaugay and McCadam have been deeply involved in project design, providing essential data and discussing how the microgrid’s DERs and infrastructure will integrate with existing facilities and future development plans.

3.3.2 Project Team

The Chateaugay microgrid project is a collaboration between the public sector, led by the Town of Chateaugay, and the private sector, led by Booz Allen Hamilton with significant support from Power Analytics, Siemens, and NYSEG. Each of the private sector partners is well qualified in the energy and project management space, and Chateaugay has strong interest in improving its energy reliability and expanding its clean energy generation capacity. Tables 18 and 19 provide details on the Project Team.

Table 18. Project Team

Background on Booz Allen Hamilton, Siemens AG, Power Analytics, and NYSEG.

Booz Allen Hamilton	**Headquarters: McLean, VA**	**Annual Revenue: $5.5 B**	**Employees: 22,700**
History and Product Portfolio: Booz Allen was founded in 1914 and in the ten decades since its founding, Booz Allen has assisted a broad spectrum of government, industry, and not-for-profit clients including the American Red Cross, all branches of the Department of Defense, the Chrysler Corporation, NASA, and the Internal Revenue Service. Booz Allen's energy business includes helping clients analyze and understand their energy use and develop energy strategies, recommending technology solutions to achieve their energy goals, and executing both self- and 3rd party funded projects including energy efficiency, renewable energy, and smart grids.			
Siemens AG	**Headquarters: Munich, Germany; U.S. Headquarters: Washington, DC**	**Annual Revenue: €71.9 B**	**Employees: 343,000**
History and Product Portfolio: Siemens AG was founded in 1847 and today is one of the world's largest technology companies. Siemens AG specializes in electronics and electrical engineering, operating in the industry, energy, healthcare, infrastructure, and cities sectors. Siemens AG develops and manufactures products, designs and installs complex systems and projects, and tailors a wide range of solutions for individual requirements. The Siemens Microgrid Team develops comprehensive solutions leveraging the strength of Siemens' portfolio – from generation sources such as gas, wind, and solar, to transmission & distribution products, to control software solutions and services.			
Power Analytics	**Headquarters: San Diego, CA**	**Annual Revenue: $10-15 MM**	**Employees: 50**
History and Product Portfolio: Founded 25 years ago, Power Analytics is a privately-held small business that develops and supports electrical power system design, simulation, and analytics software. The Company's worldwide operations include sales, distribution, and support offices located throughout North America, South America, Europe, Asia, and Africa and Australia.			
NYSEG	**Headquarters: Orange, CT**	**Annual Revenue: $1.63 B**	**Employees: 7,000**
History and Product Portfolio: A subsidiary of AVANGRID, NYSEG is an electrical and gas company operating in New York State. NYSEG provides electric service to approximately 890,000 customers and gas service to approximately 262,000 customers across more than 40% of upstate New York. AVANGRID receives yearly operating revenues of approximately $1.63 billion and is headquartered in Orange, CT.			

Table 19. Project Team Roles and Responsibilities

Table outlines roles, responsibilities, and expectations for each member of the Project Team during development, construction, and operation of the microgrid.

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
NYSEG	NYSEG will work with the Project Team to develop the concept and provide input. Their further involvement in hardware ownership or microgrid operation is undetermined at this time.	NYSEG may provide a share of the initial capital outlay that corresponds to the microgrid control infrastructure.	NYSEG may provide the necessary domain expertise to operate and maintain the microgrid. This may include responsibility for switching to island mode and regulating voltage and frequency across the microgrid's loads in both grid-connected and island mode.
Town of Chateaugay	The Town will serve as the main conduit to representatives of the critical and important facilities and other interests in the Town.	As the liaison, the Town will coordinate with all local and state parties as needed.	As the liaison, the Town will coordinate with all local, regional, and state parties as required.
Booz Allen	BAH is responsible for the delivery of the Feasibility Study and its component parts. This includes serving as the central clearinghouse of data, design, and proposal development as well as the key POC for NYSERDA on this task.	BAH will serve in an advisory and organizational role, working in a similar prime contractor capacity to provide overall design, costing, and construction management services.	BAH would serve in an outside, advisory capacity upon completion of the microgrid and during its operation.
Siemens	Siemens is the engineering and technology partner of this project. They will develop the technical design and system configuration in concert with BAH engineers and the Power Analytics team.	Siemens may have primary responsibility for the shovel-in-the-ground construction and installation of hardware and generation assets.	Ensuring proper functioning and maintenance of the microgrid technology components throughout.
Power Analytics	Power Analytics is the partner for energy software solutions. The PA team, in conjunction with Siemens and Booz Allen, is responsible for the design of the SCADA and system software components and controls.	Power Analytics may lead the installation of control and energy management software following hardware installation and in concert with Siemens.	Provide IT systems support; may play an active role in system management through the EnergyNet software platform.

Team Member	Roles and Responsibilities		
	Project Development	**Construction**	**Operation**
Suppliers	There are no suppliers required during this development phase; however, project partners and suppliers Siemens and Power Analytics are closely involved in feasibility and design portions of the project. BAH is in touch with several additional suppliers of hardware and software including Duke Energy, Enel Green Power, Anbaric Transmission, Bloom, and Energize.	Siemens or another engineering and technology firm will be the hardware supplier, including switches and other physical controls. Power Analytics or another software company will be the EMS and SCADA provider, responsible for software and server components.	The installer of the hardware and software will continue to provide maintenance and advisory services as required to ensure proper and efficient functioning of their components. The software provider will work in cooperation with NYSEG to assess the best approach to daily operations of the software system.
Financiers/Investors	The SPV will be created during the project development phase. Investors for DERs may include any of the entities mentioned in the row above.	Debt and equity investors will supply the cash required to complete the construction and installation of generation assets and microgrid controls.	Generation asset owners will realize revenues from the sale of electricity and thermal energy. NYSEG will realize revenues from payments from DER owners.
Legal/Regulatory Advisors	Regulatory advice is housed within Booz Allen. Further counsel will be retained as necessary to create the SPV and arrange financing.	Legal and regulatory will be a combination of Booz Allen, the Town, NYSEG, and any outside counsel required.	Legal and regulatory will be the responsibility of the Town, the utility, and any investors in the SPV.

3.3.3 Financial Strength

The principal shareholders in the microgrid project are NYSEG and private investors, through the SPV.

Moody's Investor Service rates NYSEG at a Baa1 credit rating. According to the Moody's rating scale, "Obligations rated Baa are judged to be medium-grade and subject to moderate credit risk and as such may possess certain speculative characteristics." NYSEG is a subsidiary of AVANGRID, a U.S. based diversified energy and utility company. AVANGRID is an affiliate of the Spanish energy company Iberdrola and employs nearly 7,000 people across the United States. NYSEG provides electric service to approximately 879,000 customers and gas service to approximately 262,000 customers across more than 40% of upstate New York. AVANGRID receives yearly operating revenues of approximately $1.63 billion.

Given the relatively reliable return on investment for solar PV arrays and efficient CHP units, the microgrid project should attract attention from outside investors. The Chateaugay microgrid will produce positive returns for investors which may be amplified by NY Prize Phase III funding.

3.4 Commercial Viability – Creating and Delivering Value (Sub Task 3.4)

The specific technologies included in the microgrid design will enable rapid and efficient transitions between grid-connected and island mode based on signals from a SCADA control center. The proven efficacy of proposed microgrid components enhances the replicability and scalability of the design. This section will discuss the technical components of the microgrid and why they were chosen.

3.4.1 Microgrid Technologies

The specific technologies included in the microgrid design were chosen to meet the goals of providing reliable and efficient power in both grid-connected and island mode, achieving automatic load following, and developing black-start capability.

A solar PV array and a natural gas-fired CHP unit were chosen as generator technologies to reduce GHG emissions and enhance the reliability of the power supply. The CHP unit will be capable of automatic load following (responding to load fluctuations within cycles, allowing the microgrid to maintain system voltage and frequency) and black starts. The unit will also reduce the need for diesel generation in emergency outage situations.

The new solar PV unit will provide a renewable component to the microgrid generation mix and is a more appropriate addition than an expanded natural gas unit. It will provide emission-free electricity during daylight hours and move Chateaugay and the state closer to the renewable generation goals set forth in state goals and the Renewable Portfolio Standards. However, PV generation will face the same problems in Chateaugay that it does elsewhere in the northeastern United States: variable weather conditions and long periods of darkness in the winter.

The Chateaugay microgrid includes numerous components that have been previously used and validated. Solar PV and natural gas CHP units are both widely used technologies, with more than 6 gigawatts of solar PV installed in 2015 in the United States. In NY State alone, there are more than 400 installed reciprocating CHP units with aggregate nameplate generating capacity that exceeds 295 MW.[17] The switch components are all industry standard and are widely used in utilities worldwide, and the intelligent electronic devices, which are robust and safe via embedded electrical protections, are similarly standard across the industry. Siemens microgrid technologies are recognized worldwide for their flexibility, reliability, and expandability—successful examples of Siemens microgrid technology at work include the Parker Ranch and Savona University microgrids.[18] Team partner Power Analytics has similarly successful implementations of its Paladin software in microgrid environments, including the 42 MW, 45,000 person UC San Diego microgrid project.[19]

[17] US DOE, https://doe.icfwebservices.com/chpdb/state/NY.
[18] Siemens case studies; available from http://w3.usa.siemens.com/smartgrid/us/en/microgrid/pages/microgrids.aspx.
[19] http://www.poweranalytics.com/company/pdf/M-12-GE-PPT-X-001-03%202012%20UCSD%20Virtual%20summit.pdf.

3.4.2 Operation

SPV investors will direct a portion of revenues to a third party operator, or NYSEG, to support the operation and maintenance of microgrid infrastructure. As the project's subject matter expert and owner of the distribution infrastructure, NYSEG will provide advice regarding the logistics of day-to-day operation. Regular maintenance and checks of equipment will be conducted based on manufacturer or installer recommendations and will ensure the proper function of all grid elements.

NYSEG will have final authority on decisions regarding the microgrid that are not automatic elevations to the state or NYPSC. Decisions regarding the proper level of generation from local assets, load following, N+1 assurance, and other similar issues will be addressed automatically in real-time by the logic controllers and the MCS. The decision algorithms will be programmed upon installation with input from the utility and with the ability to alter or revise them if operations dictate that to be the appropriate action. Interactions with the NYSEG power grid will be automatically governed by the microgrid controllers.

This analysis assumes NYSEG will purchase electricity from the SPV and distribute it across its grid. The facilities will continue to be billed for electricity via the regular NYSEG billing mechanism and cycle.

Additional fees may be imposed upon microgrid participants as a percentage of their electricity cost. However, given the extremely limited amount of time forecasted in island operation and the commensurately limited time the customers will need to rely on the microgrid, the fees are expected to be extremely marginal, if they exist at all.

3.4.3 Barriers to Completion

The barriers to constructing and operating the microgrid are primarily financial. Assuming the SPV will sell electricity to NYSEG at their current supply charge through a long-term purchase agreement, the microgrid will produce positive operating cash flows from year to year. These cash flows will recover initial investment costs after subsidies and provide positive returns to investors. The NY Sun program, Federal ITC, and NYSERDA CHP Performance Program will together offset around 28% of total project cost, and the project will not be commercially viable without these programs. Although the project will produce positive returns, the return on investment may not be competitive with stocks or other high yield investments. However, if the project receives NY Prize Phase III funding, it will be a highly attractive and competitive investment.

3.4.4 Permitting

The Chateaugay microgrid may require certain permits and permissions depending on the ultimate design choices. Proposed DERs will need to be permitted under local code, but will be located on the McCadam Cheese Company's property and therefore should not violate any public rights-of-way or zoning regulations. McCadam deploys several natural gas-fired boilers for steam throughout the year, and the CHP unit will likely require the same or similar permits as the existing boilers. However, the CHP unit will be located outside and somewhat closer to residential structures. This may entail meeting local decibel regulations that are inapplicable to the existing boilers, and may require special permitting or a special enclosure so as not to violate noise ordinances in Chateaugay.

Chateaugay is not in any EPA Criteria Pollutant Non-Attainment zones. The CHP unit will require air quality permits pursuant to the Clean Air Act.

3.5 Financial Viability (Sub Task 3.5)

The distributed energy resource assets included in the microgrid design will produce revenue streams from electricity sales to NYSEG and thermal energy sales to the McCadam Cheese Company. These assets will require significant initial capital outlay as well as annual operation and maintenance costs. The microgrid project qualifies for the NY Sun incentive, Federal ITC, and CHP Performance Program, which will partially offset the initial investment costs. Private investors will use a mix of debt and equity to finance their shares. This section will discuss the revenues, costs, and financing options associated with the microgrid project in more detail.

3.5.1 Revenue, Cost, and Profitability

The microgrid has a number of savings and revenue streams, as outlined in Table 20. The revenues will sum to approximately $1.7 million per year, while fuel, operation, and maintenance will cost around $1.16 million per year. Yearly cash flows should consistently recover operating costs and provide positive returns to investors. However, the investment may not be competitive with stocks or other high yield vehicles. NY Prize Phase III funding would make the Chateaugay microgrid an extremely attractive and competitive investment. Table 21 lays out the capital and operating costs.

Table 20. Savings and Revenues

Expected revenues and savings directly associated with operation of the microgrid and its DER assets.

Description of Savings and Revenues	Savings or Revenue	Relative Magnitude	Fixed or variable
Electricity sales from CHP unit[20]	Revenue	$1.575 MM/yr	Variable
Thermal energy sales from CHP unit	Revenue	$110,000/yr	Variable
Electricity sales from solar PV array	Revenue	$15,000/yr	Variable
Total Yearly Revenue and Savings		**$1.7 MM/yr**	Variable

[20] The Booz Allen Team calculated NYSEG's supply charge for electricity to be approximately $0.0605/kWh in the WEST zone. This is the assumed price for grid-connected sales from the CHP unit and solar arrays.

Table 21. Capital and Operating Costs

Expected costs from construction and operation of the microgrid.

Description of Costs	CapEx or OpEx	Relative Magnitude	Fixed or Variable
3.5 MW CHP unit	Capital	$7 MM	Fixed
200 kW solar PV array	Capital	$480,000	Fixed
Distributed Equipment	Capital	$220,000	Fixed
Microgrid Control System	Capital	$450,000	Fixed
IT costs (wireless and cables)	Capital	$55,000	Fixed
Total CapEx		**$8.2 MM**	Fixed
Design considerations and simulation analysis	Planning and Design	$575,000	Fixed
Project valuation and investment planning	Planning and Design	$75,000	Fixed
Assessment of regulatory, legal, and financial viability	Planning and Design	$50,000	Fixed
Development of contractual relationships	Planning and Design	$50,000	Fixed
Total Planning and Design		**$0.75 MM**	Fixed
CHP Fuel	Operating	$725,000/yr	Variable
CHP Maintenance	Operating	$365,000/yr	Variable
Solar PV Maintenance	Operating	$4,000/yr	Variable
Microgrid Control O&M	Operating	$70,000/yr	Fixed
Total OpEx		**$1.16 MM/yr**	Variable

The proposed microgrid will qualify for three existing incentive programs: the NY Sun program, the Federal solar ITC, and the NYSERDA CHP Performance Program. Together these incentive programs provide around $2.3 million over the first three years of the project, or 28% of total project capital expenditures. Other possible sources of incentive payments include NYSERDA Phase III NY Prize funding (up to $5 million but will not exceed 50% of total capital costs). See Table 22 for details on the available incentive programs.

Table 22. Available Incentive Programs

State and utility incentive programs that were included in the commercial/financial feasibility analysis and whether the incentive is required or preferred for the microgrid project to be feasible

Incentive Program	Value	Required or Preferred
NYSERDA NY Prize Phase III	$4,100,000	Preferred
NY Sun	~$145,000	Required
Federal Solar ITC	~$145,000	Required
NYSERDA CHP Performance Program	~$2,000,000	Required

3.5.2 Financing Structure

The development phase is characterized by the negotiation and execution of the construction financing and debt structure and agreements with any equity partners. The project will be best executed if it is a winner of the NY Prize Community Microgrid Phase II Competition where NYSERDA will supply 75% of the required funds for Phase II under with the balance coming from a cost-share. This is based on the Phase II cost structure as described in NYSERDA RFP-3044. Chateaugay and their Project Team will provide cash support or needed in-kind services consisting primarily of system expertise and support. Development will conclude with formal contract relationships between the utility and the customers of the microgrid, available and relevant rate and tariff information from the NYPSC, and firm financing for the construction of the project (described below).

The SPV will leverage funds from private investors to complete the construction phase. Stage 3 NY Prize funding, which could provide up to $5 million to the SPV for microgrid and DER equipment and installation, may cover half of the capital cost of the project (estimated to be approximately $4.1 million in total), which would make the Chateaugay microgrid a highly attractive investment. The Project Team has confirmed that the McCadam Cheese Company is open to providing the physical space to site the DERs.

3.6 Legal Viability (Sub Task 3.6)

Like any infrastructure project that involves development of public and private land, the Chateaugay microgrid project will require legal and regulatory agreements for ownership, access, zoning, permitting, and regulation/oversight. This section considers the various legal aspects of the microgrid project and discusses the likelihood of each becoming an obstacle to the project's success.

3.6.1 Regulatory Considerations

State and Utility Regulation

The new DERs will be regulated under relevant State code, however the process for constructing small distributed energy resources in New York is well established. The microgrid will comply with all rules governing the interconnection of generation assets to the grid, and given NYSEG's close participation in the project the Project Team does not envision any onerous requirements.

Local Regulation

All entities that require the use of public ways (i.e., for transmission or distribution facilities) must be granted permission by the presiding municipal authority in the form of a franchise or some lesser consent, depending on the scope of the usage. Towns in New York have specific statutory authority to grant franchises. As provided by N.Y. Vil. Law § 4-412, every Town Board of Trustees is empowered to grant franchises or rights to use the streets, waters, waterfront, public ways, and public places of the city.[21] "Use" encompasses occupying public rights-of-way and operation of the provider's built infrastructure to provide the public service.[22] As the distribution infrastructure already exists in Chateaugay, new permissions for the running of lines should not be a concern. As outlined in Town zoning documents, a zoning permit is required for the modification in use of any property and this may apply to the accessory addition of distributed energy resources. Given the relatively small scale of the proposed generating assets and the municipal support for the project, the Project Team does not foresee this condition as prohibitive.

Air Quality

Natural gas generators may be subject to a variety of federal permits and emission standards depending on the type of engine, the heat or electrical output of the system, how much electricity is delivered to the grid versus used onsite, and the date of construction. The specific details associated with the proposed CHP unit in Chateaugay will determine the applicability of the regulations below. CAA regulations applicable to Reciprocating Internal Combustion Engine systems will apply. These regulations include:

- National Emission Standards for Hazardous Air Pollutants (NESHAP) for Stationary Reciprocating Internal Combustion Engines (RICE): 40 CFR part 63 subpart ZZZZ
- New Source Performance Standards for Stationary Spark Ignition (SI) ICE: 40 CFR part 60 subpart JJJJ (natural gas generators)

Per EPA guidance, these regulations apply to all engine sizes, regardless of the end use of the power generated. However, further review and analysis must be conducted when details of the type and size of the generation system are confirmed.

New York state has enacted amendments to Environmental Conservation Law Articles 19 (Air Pollution Control) and 70 (Uniform Procedures) as well as DEC amended regulations 6NYCRR Parts, per the 1990 Amendments to the Clean Air Act. With this demonstration of authority, DEC received delegation of the Title V operating permit program from the US Environmental Protection Agency (EPA). Title V Permits are required for all facilities with air emissions greater than major stationary source thresholds. New York's air pollution control permitting program

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[21] N.Y. Vil. Law § 4-412.

[22] See, e.g., "Contract of April 7, 1887 between Hess et al. Commissioners & Consolidated Telegraph & Electrical Subway Co." (Con Tel and Electrical Subway Company Agreements 1886-1891.pdf).

combines the federal air operating permitting program with long-standing features of the state program. The primary rules for applications are found in 6NYCRR:

- 200 (General Provisions),
- 201 (Permits and Certificates),
- 621 (Uniform Procedures) and
- 231 (New Source Review in Non-attainment Areas and Ozone Transport Regions).

Final application of these rules will depend on the size and technology of the selected CHP unit.

3.7 Project Commercial and Financial Viability Conclusions

The proposed microgrid will provide positive returns to investors, but may require NY Prize Phase III funding to be a competitive investment. Its design includes two new DERs to be located at the McCadam Cheese Company: a 3.5 MW natural gas fired CHP unit and a 200 kW solar photovoltaic array. The SPV will provide the capital required to purchase and install these generators and will receive revenues from electricity and thermal energy sales throughout the generators' lifespan. Investors in the SPV will contribute funds to the daily operation and maintenance of the DERs, and NYSEG will leverage its local expertise to keep the microgrid components and control infrastructure running smoothly. The Project Team forecasts yearly revenues of approximately $1.7 million and yearly operation and maintenance costs of approximately $1.16 million. These estimates and value propositions are predicated on several assumptions as outlined in the executive summary.

In addition to revenues from electricity and thermal energy sales, the microgrid will provide indirect financial and non-financial benefits to Chateaugay citizens, SPV shareholders, NYSEG, and the larger Franklin County community. Improved energy resilience enhances the local population's safety and quality of life during emergency outages, and local energy generation reduces the strain on the larger energy transmission and distribution infrastructure. Future expansion of the microgrid could provide electric service to additional facilities in Chateaugay.

Permitting and regulatory challenges should be reasonably straightforward. The primary regulatory consideration will be the Clean Air Act permitting of the new CHP unit. The SPV will also need to apply for a zoning permit through the Town of Chateaugay's zoning process for the installation of the proposed DERs.

4. Cost Benefit Analysis

This section is made up of seven sections in addition to the introduction:

- ***Section 1*** analyzes the *facilities connected to the microgrid* and their energy needs.
- ***Section 2*** discusses the *attributes of existing and proposed distributed energy resources*, including factors such as nameplate capacity and expected annual energy production.
- ***Section 3*** analyzes *potential ancillary services sales and the value of deferring transmission capacity investments*.

- ***Section 4*** reviews the *overall costs* associated with construction and installation of the microgrid as well as the fuel, operation, and maintenance costs required over the lifetime of the microgrid.
- ***Sections 5 and 6*** discuss the *community benefits* of maintaining power during a grid-wide outage and outline the costs associated with operating the microgrid in island mode.
- ***Section 7*** presents the Industrial Economics (IEc) *benefit-cost analysis report and associated Project Team commentary.*

4.1 Facility and Customer Description (Sub Task 4.1)

The Chateaugay microgrid will include ten facilities from various rate classes and economic sectors. NYSERDA designates three primary rate classes based on type of facility and annual electricity consumption: residential, small commercial (less than 50 MWh per year), and large commercial (greater than 50 MWh per year). See Table 23 for basic statistics on each facility's energy usage. Four of the proposed microgrid facilities belong to the large commercial rate class requiring approximately 9,651 MWh of electricity per year. One of the proposed microgrid facilities belongs to the small commercial rate class requiring approximately 23 MWh of electricity per year. Five of the proposed microgrid facilities belong to the residential rate class requiring approximately 1,329 MWh of electricity per year. Additionally the average aggregate demand in 2014 was 1.25 MW and rose as high as 3.11 MW.

There are three kinds of facilities in the microgrid: public, commercial, and residential. The public facilities are the fire station, local DPW complex, the Chateaugay town garage, and a primary water treatment facility which consumes approximately 8.3% of the microgrid's total annual usage. The commercial facility is the McCadam Cheese Company that consumes approximately 79.6% of the microgrid's total annual usage. The residential facilities includes five load clusters and compromises 12.1% of the microgrid's total annual electricity usage.

The combination of existing and proposed generation assets included in the microgrid design will be capable of meeting 100% of average aggregate facility energy usage during a major power outage, but may approach their generation limits if several large facilities simultaneously reach peak energy use.

Some of the facilities do not operate 24 hours a day or have very low overnight demand, such as the residential load clusters, and will only operate 12 hours per day during grid-connected mode. However some critical facilities that normally operate less than 24 hours per day may need to operate continuously in emergency island-mode situations. For example, the village office normally requires electricity for lighting, electrical appliances, and heating/cooling during the daytime hours, but could also be used in emergencies. This will extend its electricity usage window from 12 hours per day to 24 hours per day. For information on each facility's average daily operation during a major power outage, see Table 23.

Table 23. Facility and Customer Detail Benefit[23]

Table provides details about each facility and customer served by the microgrid, including average annual electricity usage, 2014 peak electricity demand, and hours of electricity required during a major power outage.

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[23] Load data was provided to Booz Allen by Con Ed.

4.2 Characterization of Distributed Energy Resource (Sub Task 4.2)

The microgrid design incorporates distributed energy resources, including one proposed single CHP unit, and one proposed solar PV array. The proposed CHP unit and solar PV array will produce an average of 3.003 MW of electricity throughout the year.[24]

As shown in Table 24 the CHP system has a nameplate capacity of 3.5 MW and will operate nearly continuously. Assuming a capacity factor of 85%, the CHP unit will produce approximately 26,061 MWh of electricity over the course of the year. If a major power outage occurs, the CHP unit will produce an average of 71.4 MWh of electricity per day, which would provide over 100% of the microgrid's average daily demand. Assuming a heat rate of 9.5 million British Thermal Units (MMBTU) per MWh,[25] the CHP unit will incur a fuel cost of approximately $27/MWh.[26]

Limited by weather conditions, natural day-night cycles, and assuming a capacity factor of 14% the 0.2 MW solar PV array is expected to produce a combined 245 MWh per year. Because many outages are caused by severe weather events, solar panels cannot be relied upon to provide energy during emergency outages without supplementary battery storage. However, on average, the solar arrays will produce a combined 0.67 MWh of electricity per day, which represents 2.25% of average daily electricity demand. Maintenance costs for the solar array will be around $4,000 per year,[27] which means the marginal cost of producing solar electricity will be about $34/MWh.[28]

See Table 24 for a detailed list of all proposed and existing distributed energy resources in Chateaugay.

[24] NG generator capacity factor: 85% (EPA estimate for 10 MW generator, http://www3.epa.gov/chp/documents/faq.pdf), Solar array capacity factor: 14% (NREL PV Watts Calculator).
[25] 2013 EIA average for natural gas fired Gas Turbine (http://www.eia.gov/electricity/annual/html/epa_08_02.html).
[26] Price of natural gas: $2.92 per Mcf (cost of natural gas from St Lawrence Gas).
[27] Annual fixed O&M cost: $20/kW per year (NREL, http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html).
[28] Capital cost: $717,500 (pro-rated from Siemens estimate for 2 MW solar array), Variable cost: 30 years of production at a cost of $20/kW per year (Siemens lifecycle estimate, NREL).

Table 24. Distributed Energy Resources

Table lists DERs incorporated in the microgrid, including their energy/fuel source, nameplate capacity, estimated average annual production under normal operating conditions, average daily production in the event of a major power outage, and fuel consumption per MWh generated (for fuel-based DERs).

Distributed Energy Resource Name	Facility Name	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Expected Daily Production During Major Power Outage (MWh)	Potential Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh	
							System fuel	Units of MMBTUs
DER1 - CHP System	McCadam Cheese Company	Natural Gas	3.5	26,061	71.4	84	9.26 Mcf	9.5 MMBTUs
DER2 - Solar PV Array	McCadam Cheese Company	Sunlight	0.2	245.28	0.67	1.6[29]	N/A	N/A

[29] Assumes 10 hours of production (daylight) at 80% of capacity.

4.3 Capacity Impacts and Ancillary Services (Sub Task 4.3)

4.3.1 Peak Load Support

The microgrid's proposed generation assets will operate nearly continuously throughout the year, providing a constant level of load support to the greater grid. Although continuous operation will limit the CHP unit's ramp-up capability during peak demand events, it will also maximize revenue for owner of the microgrid. See Table 25 for the maximum generation capacities of the proposed and existing DERs.

The proposed solar arrays will be at their most productive on days with higher solar irradiance when peak demand events are common, thus providing peak load support when it is most needed. They will provide around 0.028 MW (including capacity factors) of load support on average over the course of a year. However, their generation depends on weather conditions and time of day, therefore solar arrays are not a reliable source of peak load support.

Table 25. Distributed Energy Resource Peak Load Support

Table shows the available capacity and impact of the expected provision of peak load support from each DER.

Distributed Energy Resource Name	Facility Name	Available Capacity (MW)	Does distributed energy resource currently provide peak load support?
DER1 - CHP System	McCadam Cheese Company	Maximum of 3.5	No
DER2 - Solar PV Array	McCadam Cheese Company	Maximum of 0.2	No

4.3.2 Deferral of Transmission/Distribution Requirements

The 3.003 MW of average local generation produced by the DERs will slightly reduce the amount of electricity imported from the larger NYISO and Con Ed power lines. Although these power lines will last up to one hundred years if well maintained,[30] they can only transmit a limited amount of power. As demand for electricity in Chateaugay increases, the lines may need to be supplemented to handle additional load.

4.3.3 Ancillary Service

None of the existing and proposed generation resources in Chateaugay will participate in ancillary services markets. Although the CHP system can change output quickly enough to qualify for some paid NYISO ancillary service programs, it will not have sufficient capacity to participate. Most paid NYISO ancillary service programs require at least 1 MW of output regulation, which represents 28% of the CHP unit's maximum output. If the CHP system runs at projected levels, it will never have the minimum regulation capacity available.

Although the CHP unit will not participate in paid NYISO ancillary service programs, it will provide many of the same ancillary services to the local Chateaugay grid. For example, the CHP will provide frequency regulation as a by-product of its operation. The Chateaugay microgrid

[30] Professor John Kassakian, MIT: http://engineering.mit.edu/ask/how-do-electricity-transmission-lines-withstand-lifetime-exposure-elements.

connected facilities will receive the benefits from provided ancillary services, but these will not be paid services and will not generate any new revenue streams—no services are being bought or sold. Instead, provision of ancillary services will represent a direct value to microgrid connected facilities.

4.3.4 Development of a Combined Heat and Power System

McCadam will be a steady and reliable customer for all of the steam generated by the CHP facility. At normal levels of operation, the CHP unit will produce approximately 3,330 MMBTUs of steam per month. This will meet approximately 25% of McCadam's average monthly thermal energy demand, which is around 13,750 MMBTUs.[31] By purchasing steam from the CHP unit, McCadam will replace around 40,000 MMBTUs of natural gas with co-generated steam every year.

4.3.5 Environmental Regulation for Emission

The microgrid's generation assets will drive a net 2,794 MTCO_2e (metric tons CO_2 equivalent) increase in GHG emissions in Chateaugay as compared to the New York State energy asset mix. The proposed generation assets will produce approximately 26,306 MWh of electricity per year. The proposed CHP unit will emit approximately 14,304 MTCO_2e per year, [32] while the solar arrays emit none. The current New York State energy asset mix would emit approximately 9,548 MTCO_2e to produce the same amount of electricity[33] and natural gas-fired boilers would emit around 1,961 MTCO_2e to produce the same amount of thermal energy.[34] The microgrid's generation assets will therefore result in a net increase in emissions by 2,794 MTCO_2e.

The microgrid's generation assets will not need to purchase emissions permits to operate and will not exceed current New York State emissions limits for generators of their size. The New York State overall emissions limit was 64.3 MMTCO_2e in 2014, and will begin decreasing in the near future. The state sells an "allowance" for each ton of CO_2e emitted in excess of the limit at allowance auctions, but does not require assets under 25 MW to purchase allowances. The CHP unit is defined as a "small boiler" by NYS Department of Environmental Conservation (NYS DEC) limits (fuel input of 10-25 MMBTU/hour). The NYS DEC is currently developing output-based emissions limits for distributed energy resource assets. These limits on SO_2, NO_x, and particulate matter (to be captured in 6 NYCRR Part 222) should be published in late 2015 or early 2016. The main source of emissions regulations for small boilers is currently the EPA 40 CFR part 60, subpart JJJJJJ—however, this law does not include gas-fired boilers.

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[31] Data supplied by the Con Edison.
[32] CHP System Emissions Rate: 0.51 MTCO2e/MWh (assuming 117 lb CO2e per MMBTU; EIA, http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11).
[33] Assuming an asset mix of 15% coal, 31% natural gas, 6% oil, 17% hydro, 29% nuclear, 1 % wind, 1% sustainably managed biomass, and 1% "other fuel". This adds up to around 0.36 MTCO_2e/MWh. Info from EPA (http://www3.epa.gov/statelocalclimate/documents/pdf/background_paper_3-31-2011.pdf).
[34] Average emissions rate for natural gas boilers: 0.053 MTCO_2e/MMBTU. Info from EIA (117 lb CO_2 per MMBTU; http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11).

The natural gas generator will require an operating permit in addition to other construction permits. The costs of obtaining this permit will be in line with the cost of a construction permit and not comparable to the price of emissions allowances.

Table 26 catalogs the CO_2, SO_2, NO_x, and Particulate Matter (PM) emissions rates for the CHP system.

Table 26. Emission Rates

Table shows the emission rates for each DER per MWh and per year. Notice the rates vary drastically for each emissions type (CO_2, SO_2, NO_x).

Distributed Energy Resource Name	Location	Emissions Type	Emissions Per MWh (Metric Tons/MWh)
DER1 - CHP System	McCadam Cheese Company	CO_2	0.553
		SO_2	0.0000067[35]
		NO_x	0.00055[36]

4.4 Project Costs (Sub Task 4.4)

4.4.1 Project Capital Cost

The microgrid design requires the following new pieces of distributed equipment across the microgrid:

- A control system to provide one point of control for operating the microgrid and synthesizing real-time electricity data from the connected facilities.
- Intelligent Electronic Devices to interface with the 34 kV feeder line
- Automated breakers installed throughout Chateaugay to allow the microgrid to isolate and maintain power to the microgrid connected facilities.
- Grid-paralleling switchgear to synchronize each generator's output to the system's frequency.

The total installed capital cost of the equipment is estimated to be $725,000 for distributed controls and IT equipment. The Project Team estimates the CHP system and solar PV array will carry an installed cost of $7,000,000 and $480,000, respectively.[37] This brings the total installed capital cost $8.2 million, not including interconnection fees and site surveys. Additionally the estimated capital cost does not account for any financial incentives or tax credits that may lower the overall cost of the microgrid. See Tables 27 and 28 below for estimated installed costs for each microgrid component.

The Project Team estimates nearly every piece of microgrid equipment has a useful lifespan of 20 years. The only component with a shorter lifespan will be the microgrid control system

[35] CHP calculator, EPA.

[36] EPA, http://www3.epa.gov/chp/documents/faq.pdf.

[37] CHP Capital Cost: $1,600/kW, pro-rated from Siemens 2 MW CHP system estimate, Solar PV Capital Cost: $1,750/kw, pro-rated from Siemens 2 MW Solar PV estimate.

(Siemens SICAM PAS or equivalent), which will be replaced by more advanced software after 7-8 years. Operating and maintenance cost data in Table 28 does not include replacement costs for microgrid components.

Table 27 details capital cost of the distributed equipment and IT; it includes equipment such as the microgrid control system and centralized generation controls that will allow the operator and electronic controllers to manage the entire microgrid.

Table 27. Distributed Equipment Capital Cost

Estimated costs and lifespan of the equipment associated with the microgrid.

Equipment Capital Costs				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
Microgrid Control System (Siemens SICAM PAS or equivalent)	1 Primary 1 Back-up	$50,000	7 - 8	Control system responsible for operating the microgrid sequencing and data concentration under all operating modes.
Microgrid Control Center (Siemens MGMS or equivalent)	1	$300,000	20	Provides data trending, forecasting, and advanced control of generation, loads and AMI/SCADA interface, interface to NYISO for potential economic dispatch.
Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay or equivalent)	5 New 2 Upgrade	$150,000 $10,000	20	Upgraded breakers/switches at 2 distribution overhead switches. Isolate feeders from microgrid
Generation Controls (OEM CAT, Cummins, etc.)	1	$4,000	20	Serves as the primary resource for coordinating the paralleling load matching of spinning generation.
PV Inverter Controller (OEM Fronius or equivalent)	1	$4,000	20	Controls PV output and sends data to SCADA and EMS for forecasting.
Network Switches	7	$5,000	20	Located at IEDs and controllers for network connection, allowing remote monitoring and control.
WiMax Base Station	1	$8,000	20	Located near microgrid control cabinet. Communicates wirelessly with WiMax subscriber units for remote control and monitoring of breakers and switches. Should be installed at high location.
WiMax Subscriber Units	7	$14,000	20	Each subscriber unit can communicate back to the WiMax base station for SCADA monitoring and control or remote relay to relay GOOSE messaging.

Equipment Capital Costs				
Capital Component	Quantity	Installed Cost ($) (+/- 30%)	Component Lifespan (Years)	Purpose/Functionality
WiMax configuration and testing	1	$23,000	-	The configuration and testing of the WiMax hardware
Installation Costs	-	$150,000	-	Installation of capital components in the microgrid

Table 28. Capital Cost of Proposed Generation Units

Table displays the estimated costs and lifespan of the equipment associated with the generation units of the microgrid.

Proposed Generation Units				
Capital Component	Quantity	Installed Cost ($) (+/- 30%)	Component Lifespan (Years)	Purpose/Functionality
3.5 MW CHP System	1	$7,000,000	20	Generation of electricity
0.2 MW PV System	1	$480,000	30	Generation of electricity

The microgrid IT infrastructure will also require Cat-5e Ethernet for communication between distribution switches, generation switchgear, PV inverters, and network switches. The design uses Cat-5e cabling, including RJ-45 connectors at $0.61 per cable.[38] The total installation cost of cabling is approximately $5.65 per foot for Cat-5e cables. [39] The Project Team will use the existing cabling infrastructure to install the communications cables, thereby avoiding the high costs of trenching the proposed lines. The estimated total cost for the microgrid IT infrastructure is around $10,000. [40]

4.4.2 Initial Planning and Design Cost

The initial planning and design of the microgrid includes four preparation activities and total to approximately $0.75 million.

1. The first set of activities are the design considerations and simulation analysis which will cost approximately $575,000 to complete.
2. The second activity focuses on the financial aspects of the project including project valuation and investment planning which will cost approximately $75,000.
3. The third activity focuses on the legal aspects of the project including an assessment of regulatory issues and legal viability which will cost approximately $50,000.
4. The fourth activity focuses on the development of contractual relationships with key partners will cost approximately $50,000.

[38] Commercially available RJ-45 connectors, $0.30 per connector.
[39] Installation costs for Cat5e: $5.45/ft. Component cost for Cat5e: $0.14/ft (commercially available).
[40] The Project Team estimated ~550 feet of Cat5e and other network switches will be necessary.

A breakout of the initial planning and design costs are illustrated in Table 29 below.

Table 29. Initial Planning and Design Cost

Table displays estimates and descriptions for engineering, legal, and financing costs involved in initial planning and design of the microgrid.

Initial Planning and Design Costs ($)[41]	What cost components are included in this figure?
$575,000	Design considerations and simulation analysis
$75,000	Project valuation and investment planning
$50,000	Assessment of regulatory, legal, and financial viability
$50,000	Development of contractual relationships
$750,000	**Total Planning and Design Costs**

4.4.3 Operations and Maintenance Cost

The proposed DERs will incur fixed operation and maintenance costs, including fixed annual service contracts.

Annual service for the proposed CHP unit will cost approximately $365,000.[42] The microgrid owner will also incur $4,000 per year in total costs for annual fixed system service agreements for the solar PV array and backup generators. [43]

The DER assets will also incur variable O&M costs that fluctuate based on output. These include fuel and maintenance costs outside of scheduled annual servicing. First, the CHP system will require capital for fuel, consumable chemicals, and other operating expenses. The average price of natural gas is $4.00/Mcf, which translates to an average fuel cost of $37/MWh for the CHP unit.

The solar PV arrays will not require fuel to operate, and it should not require service outside of the normally scheduled down-time. Normally scheduled down-time should cost approximately $20/kW per year.[44]

Annual service for all non-DER microgrid components will cost approximately $70,000 per year.[45] Table 30 outlines all fixed O&M costs associated with normal operation of the DERs.

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[41] Estimates developed by Booz Allen Project Team and industry experts.

[42] CHP O&M: $0.01/kWh. (US DOE Industrial Technologies Program).

[43] $5,000 for solar PV array ($20/kW per year), $4.60/kW per year for backup diesel generators (Electric Power Research Institute, "Costs of Utility Distributed Generators, 1-10 MW") and $1,500 for CHP system (Pete Torres, Prime Power; yearly service for small scale natural gas generator).

[44] NREL (projects $0/kWh variable maintenance costs): http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.

[45] O&M for non-DER microgrid components: $70,000/year (Siemens).

Table 30. Fixed Operating and Maintenance Cost

Table displays estimated values and descriptions of the fixed O&M costs associated with operating and maintaining the microgrid's DERs.

Fixed O&M Costs ($/year)	What cost components are included in this figure?
~ $365,000	CHP system Service Agreement – Annual costs of maintenance and servicing of unit
~ $4,000 (total)	Solar PV System Service Agreements – Annual costs of maintenance and servicing of unit
$70,000	Non-DER Microgrid Components Service Agreement - Annual costs of maintenance and servicing of components

4.4.4 Distributed Energy Resource Replenishing Fuel Time

The CHP unit will have a continuous supply of fuel unless the pipeline is damaged or destroyed. The CHP system can operate continuously given properly functioning gas pipelines, therefore there is effectively no maximum operating duration for the CHP system in island mode. DERs such as diesel generators have limited tank sizes and have clear maximum operating times in island mode.

4.5 Costs to Maintain Service during a Power Outage (Sub Task 4.5)

4.5.1 Backup Generation Cost during a Power Outage

All microgrid generation assets will serve as backup generation in the event of an extended power outage. The CHP system will be the most reliable and productive of the DERs, providing an average of 2.975 MW to the microgrid at any given time. Because the CHP system will use natural gas via pipeline as fuel, disruptions to its fuel source are unlikely. The CHP system can generate on average 84 MWh per day, using approximately 777 Mcf (798 MMBTU) of natural gas. The CHP system will not require startup or connection costs in order to run during island mode and should not incur any daily variable costs other than fuel.

The solar array will be available for backup generation during a power outage, but its production is too inconsistent for it to qualify as a true backup generator. Extreme weather is responsible for many emergency outages in New York State, and such weather will greatly reduce the output of the solar panels. However, when high state-wide electricity demand on the most irradiated days of summer causes outages, the solar panels will be nearing their most productive and could provide up to 0.2 MW of load support to the Chateaugay microgrid. Table 31 shows all of the costs associated with operating the DERs during a power outage, including fuel and variable O&M costs.

Table 31. Cost of Generation during a Power Outage

Table lists each generation unit and its respective energy source. Additionally, nameplate capacity, expected power outage operating capacity, and daily average production of power (in MWh) is detailed. Lastly quantity and units of daily fuel and operating costs (both one-time and ongoing) are described.

DER	Energy Source	Nameplate Capacity (MW)	Expected Operating Capacity (%)	Avg. Daily Production During Power Outage (MWh/ Day)	Fuel Consumption per Day		One-Time Operating Costs ($)	Ongoing Operating Costs per day – Fuel and variable O&M
					Quantity	Unit		
DER1 - CHP System	Natural Gas	3.5	100%	84	777.7	Mcf	N/A	4,110[46]
DER2 - Solar PV Array	Sunlight	0.2	14%	0.672[47]	N/A	N/A	N/A	10.96

4.5.2 Cost to Maintain Service during a Power Outage

There are no costs associated with switching the microgrid to island mode during a power outage other than the operational costs already accounted for above. Please refer to Table 31 for one-time and ongoing costs of microgrid generation per day. The proposed microgrid has the capacity to support all the connected facilities, which means even those facilities with backup generators will not have to rely on or pay for on-site backup power. Facilities not connected to the microgrid will experience power outages and may need emergency services depending on the severity of the emergency event. Any other cost incurred during a wide spread power outage will be related to the emergency power (i.e. portable generators) rather than electricity generation costs.

4.6 Services Supported by the Microgrid (Sub Task 4.6)

Most of the facilities to be connected to the microgrid are public or residential facilities that serve the community of Chateaugay and the surrounding area (such as the fire department and the primary water treatment facility). For estimates of the population served by each critical facility, see Table 32.

Backup power supplied by the microgrid should provide 100% of each facility's electricity demand during outage situations. However, if backup power from the microgrid is not available, the critical services provided by these facilities will be severely hampered. Some critical services do not require electricity (e.g. driving a police car to the scene of a crime), while others are completely dependent on a stable power supply (e.g. some municipal buildings or local water sanitizing operations). Based on the portfolio of services that each facility provides and the

[46] = Daily fuel cost during an outage (Mcf/day) + (Yearly O&M/365).

[47] This output assumes that the PV arrays are still operational after an emergency event. In the case that the PV arrays are damaged, the microgrid will use the CHP system as the key source of emergency power.

electricity dependency of each service, Table 32 provides an estimate of how effectively each facility can perform its normal services without electricity.

Table 32. Critical Services Supported

Table details critical services supported by the microgrid during an outage. The table also shows the percentage of services lost for each facility when backup power is not available during an outage.

Facility Name	Population Served by This Facility	Percentage Loss in Service During a Power Outage[48]	
		When Backup Power is Available	When Backup Power is Not Available
Fire Station	2,200	0%	> 50%
Department of Public Works, Village Office, and Storage	2,200	0%	> 75%
McCadam Cheese Company	~ 110	0%	> 90%
Chateaugay Town Garage	2,200	0%	> 50%
Primary Water	2,200	0%	> 90%
Load Cluster 1	~ 95	0%	> 50%
Load Cluster 2	~ 55	0%	> 50%
Load Cluster 3	~ 125	0%	> 50%
Load Cluster 4	~ 150	0%	> 50%
Load Cluster 5	~ 120	0%	> 50%

4.7 Industrial Economics Benefit-Cost Analysis Report

As follows is a direct cost-benefit analysis deliverable from Industrial Economics. IEc was hired by NYSERDA to conduct a benefit-cost analysis of each feasibility study. The benefit-cost analysis of the Chateaugay microgrid was delivered to the Project Team on March 3, 2016.

4.7.1 Project Overview

As part of NYSERDA's NY Prize community microgrid competition, the Town of Chateaugay has proposed development of a microgrid that would serve ten local facilities:

- The Chateaugay Fire Station
- The Chateaugay Department of Public Works and Village Office
- The Chateaugay Town Garage, which acts as a garage for emergency vehicles
- The McCadam Cheese Company, a local cheese manufacturing plant
- Primary Water, a local water filtration and pumping plant
- Five clusters of residences, which for purposes of this analysis will be referred to as:

[48] Booz Allen estimated % loss based on energy demands and services provided for Emergency Services, Municipal Services, Health Services, and Education Services based on previous research by NIH and CDC (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1497795/; http://www.ncbi.nlm.nih.gov/pubmed/15898487; http://emergency.cdc.gov/disasters/poweroutage/needtoknow.asp).

- "Load Cluster 1" - 24 residences
- "Load Cluster 2" - 13 residences
- "Load Cluster 3" - 31 residences
- "Load Cluster 4" - 35 residences
- "Load Cluster 5" - 30 residences

The microgrid would be powered by two new distributed energy resources – a 3.5 MW natural gas unit and a 200 kW photovoltaic array. The natural gas unit would incorporate CHP systems that would produce thermal energy as well as electricity. The town anticipates that the new natural gas unit and photovoltaic system would produce electricity for the grid during periods of normal operation. The system as designed would have sufficient generating capacity to meet average demand for electricity from the ten facilities during a major outage. Project consultants also indicate that the system would have the capability of providing black start support to the grid.

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.

4.7.2 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 benefit cost analysis (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. Of note, 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.[49] 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 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[50]

4.7.3 Results

Table 33 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

[49] 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 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 using a three percent discount rate, to value CO_2 emissions. As the NYPSC 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.]

[50] 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.

need to equal or exceed 2.6 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

Table 33. BCA Results (Assuming 7 Percent Discount Rate)

Economic Measure	Assumed Average Duration of Major Power Outages	
	Scenario 1: 0 Days/Year	Scenario 2: 2.6 Days/Year
Net Benefits - Present Value	-$7,560,000	$48,100
Benefit-Cost Ratio	0.8	1.0
Internal Rate of Return	-3.6%	6.7%

Scenario 1

Figure 6 and Table 34 present the detailed results of the Scenario 1 analysis.

Figure 6. Present Value Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

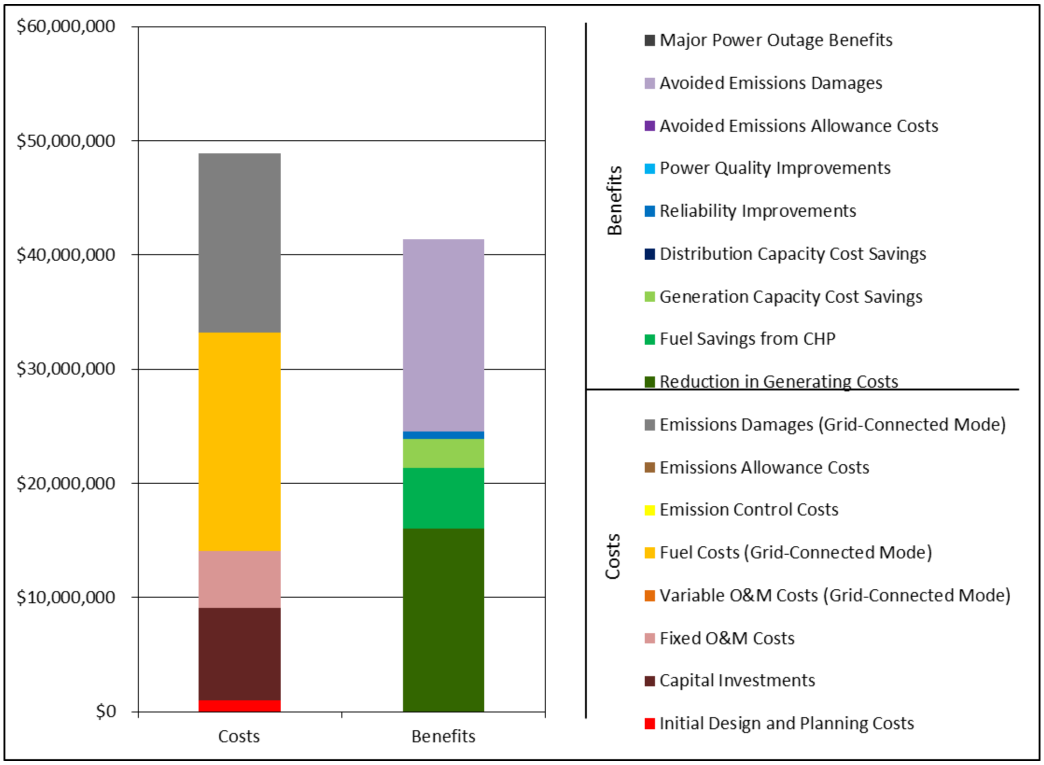

Table 34. Detailed BCA Results, Scenario 1

(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	$1,000,000	$88,200
Capital Investments	$8,080,000	$712,000
Fixed O&M	$4,980,000	$439,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$19,200,000	$1,690,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$15,700,000	$1,020,000
Total Costs	**$48,900,000**	
Benefits		
Reduction in Generating Costs	$16,000,000	$1,410,000
Fuel Savings from CHP	$5,340,000	$471,000
Generation Capacity Cost Savings	$2,550,000	$225,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$637,000	$56,200
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$8,920	$787
Avoided Emissions Damages	$16,800,000	$1,100,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$41,400,000**	
Net Benefits	**-$7,560,000**	
Benefit/Cost Ratio	**0.8**	
Internal Rate of Return	**-3.6%**	

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 $1.0 million. The present value of the project's capital costs is estimated at approximately $8.1 million, including costs associated with installing a microgrid control system; equipment for the substations that will be used to manage the microgrid; the IT infrastructure for the microgrid; the new 3.5 MW natural gas unit with CHP capabilities; and the new 200 kW photovoltaic array. Operation and maintenance of the entire system would be provided under fixed price service contracts, at an estimated annual cost of approximately $439,000. The present value of these O&M costs over a 20-year operating period is approximately $5.0 million.

Variable Costs

The most significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the system's primary generator. 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 State Energy Plan (SEP), adjusted to reflect recent market prices.[51] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $19.2 million.

The analysis of variable costs also 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 annual damages attributable to emissions from the new natural gas generator are estimated at approximately $1.0 million. 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 $15.7 million.

Avoided Costs

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. In the case of the Town of Chateaugay's proposed microgrid, the primary source of cost savings would be a reduction in demand for electricity from bulk energy suppliers, with a resulting reduction in generating costs. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $16.0 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. The reduction in demand for electricity from bulk energy suppliers would also reduce emissions of CO_2 and particulate matter from these sources, and produce a shift in demand for SO_2 and NO_x emissions allowances. The present value of these benefits is approximately $16.8 million.[52]

The microgrid's CHP system could deliver additional cost savings over the microgrid's 20-year operating period by reducing the amount of fuel required to heat the facilities it would serve. The analysis estimates the present value of these savings to be approximately $5.3 million.

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.[53] Based on standard capacity factors for solar and natural gas generators, the Project Team estimates the project's impact on demand for generating capacity to

[51] The model adjusts the State Energy Plan's natural gas and diesel price projections using fuel-specific multipliers that are 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.

[52] Following the New York Public Service Commission's 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. [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.

[53] Impacts on 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.

be approximately 3.003 MW per year (the team estimates no impact on distribution capacity). Based on this figure, the BCA estimates the present value of the project's generating capacity benefits to be approximately $2.6 million over a 20-year operating period.

The Project Team has indicated that the proposed microgrid would be designed to provide ancillary services, in the form of black start support, to the 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 market for black start support is 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 this service.

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 $56,200 per year, with a present value of $637,000 over a 20-year operating period. This estimate is calculated 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:[54]

- System Average Interruption Frequency Index – 1.03 events per year
- Customer Average Interruption Duration Index – 118.2 minutes[55]

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.[56] 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.

[54] www.icecalculator.com.
[55] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for New York State Electric & Gas.
[56] http://www.businessweek.com/articles/2012-12-04/how-to-keep-a-generator-running-when-you-lose-power#p1.

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.[57,58]

As noted above, the Town of Chateaugay's microgrid project would serve ten facilities or residential load clusters. The project's consultants indicate that at present, none of these facilities is equipped with a backup generator. Should there be a power outage, these facilities could maintain operations by bringing in portable generators. When operating on portable generators, the McCadam Cheese Company would maintain a 50 percent level of service, while the other nine facilities or load clusters would have sufficient power to maintain all services. Table 35 lists the Project Team's cost estimates for maintaining service with portable generators. In the absence of backup power - i.e., if the backup generator failed and no replacement was available - all of the facilities or load clusters would experience a 50 to 90 percent loss in service capabilities (see Table 35).

[57] 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.

[58] 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.

Table 35. Backup Power Costs and Level of Service, Scenario 2

Facility Name	Cost of Maintaining Service with Portable Generator ($/Day)	Percent Loss in Service with Backup Generation is Not Available
Chateaugay Fire Station	$380	50%
Chateaugay Department of Public Works and Village Office	$1,470	75%
Chateaugay Town Garage	$352	50%
McCadam Cheese Company	$17,216	90%
Primary Water	$772	90%
Load Cluster 1 (24 residences)	$1,119	50%
Load Cluster 2 (13 residences)	$352	50%
Load Cluster 3 (31 residences)	$1,470	50%
Load Cluster 4 (35 residences)	$1,269	50%
Load Cluster 5 (30 residences)	$1,277	50%

The information provided above serves as a baseline for evaluating the benefits of developing a microgrid. In addition, the assessment of Scenario 2 assumes that in all cases, the supply of fuel necessary to operate backup generators would be maintained indefinitely, and that at each facility there is a 15 percent chance that the backup generator would fail.

The economic consequences of a major power outage also depend on the value of the services the facilities of interest provide. The analysis calculates the impact of a loss in the city's fire, residential electric, and water services using standard FEMA methodologies that characterize the value of these services. The impact of a loss in service at other facilities is based on the following value of service estimates, which were developed using the U.S. Department of Energy's ICE Calculator:

- For the Department of Public Works and Village Office, a value of approximately $41,000 per day
- For the Town Garage, a value of approximately $7,000 per day
- For the McCadam Cheese Company, a value of approximately $405,000 per day

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for the six facilities is approximately $259,000 per day.

Summary

Figure 7 and Table 36 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 2.6 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 7. Present Value Results, Scenario 2

(Major Power Outages Averaging 2.6 Days/Year; 7 Percent Discount Rate)

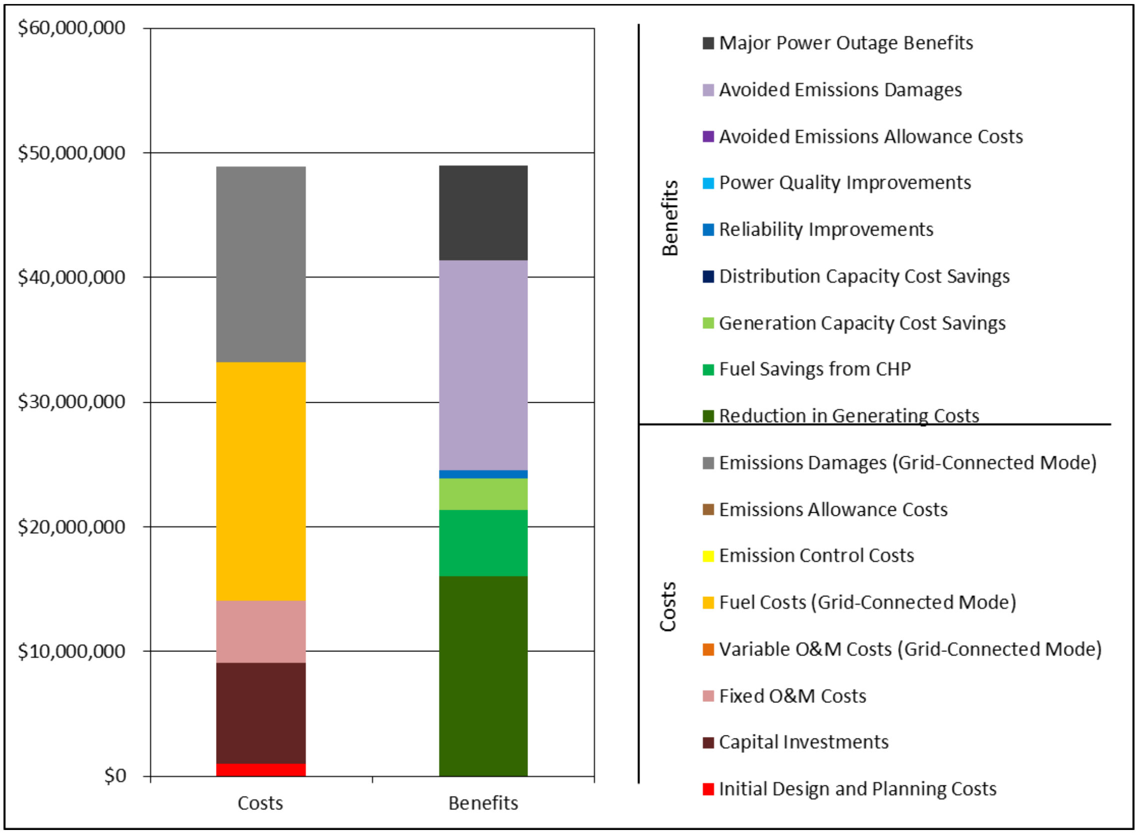

Table 36. Detailed BCA Results, Scenario 2

(Major Power Outages Averaging 2.6 Days/Year; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value Over 20 Years (2014$)	Annualized Value (2014$)
Costs		
Initial Design and Planning	$1,000,000	$88,200
Capital Investments	$8,080,000	$712,000
Fixed O&M	$4,980,000	$439,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$19,200,000	$1,690,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$15,700,000	$1,020,000
Total Costs	**$48,900,000**	
Benefits		
Reduction in Generating Costs	$16,000,000	$1,410,000
Fuel Savings from CHP	$5,340,000	$471,000
Generation Capacity Cost Savings	$2,550,000	$225,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$637,000	$56,200
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$8,920	$787
Avoided Emissions Damages	$16,800,000	$1,100,000
Major Power Outage Benefits	$7,610,000	$674,000
Total Benefits	**$49,000,000**	
Net Benefits	**$48,100**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**6.7%**	

The Project Team assumed an electricity sales price of $0.061 per kWh in Chateaugay. This is the supply cost for NYSEG, the average amount spent by NYSEG to import electricity into their distribution system. On a long term, fixed volume PPA, the Project Team believes this to be the most accurate pricing model. Industrial Economics modeled the location-based marginal price (LBMP) for the local NYISO zone to price electricity sales. The LBMP is effectively the average spot market price, peaking on summer afternoons and dropping to nearly zero in low demand hours. While the LBMP would be an appropriate price for intermittent and unreliable grid sales, the proposal herein supports reliable, continuous electricity injections into the NYSEG grid. In Chateaugay, the Mohawk Valley LBMP is $33.63 per MWh[59], or $0.034 per kWh, a more than 44% reduction in price from the supply cost. The benefits allowed for capacity cost reductions do not bring the electricity prices to parity. This has a predictable influence on the economics of the projects and is the driving force behind the divergent cost benefit analyses developed by the Project Team and by IEc. The Project Team is unaware of any community microgrid business model or generation set that is financially self-sufficient at the LBMP.

[59] Average according to IEc cost-benefit model.

5. Summary and Conclusions

5.1 Lessons Learned and Areas for Improvement

The lessons learned from the Chateaugay microgrid feasibility study are divided into two parts. The first part in Section 5.1.1 highlights Chateaugay-specific issues to be addressed moving forward. The second part in Sections 5.1.2 and 5.1.3 addresses statewide issues, replicability, and the perspectives of many stakeholder groups. These lessons learned may be generalized and applied across the State and NY Prize communities.

5.1.1 Chateaugay Lessons Learned

Through the Chateaugay microgrid feasibility study, the Project Team learned site-specific lessons applicable to other communities in its portfolio and around the state.

Chateaugay is unique among smaller, rural communities in that there is a both a natural gas supply and a large industrial facility with a significant thermal demand. Thermal load and natural gas availability, in addition to overall project size, are often chief determinants of what is possible and in Chateaugay they propel the project to feasibility. Chateaugay, unlike many other rural communities, is unconstrained by its relatively low density: many desired critical loads are electrical adjacent on one feeder. This feature allows for an integrated microgrid solution that requires somewhat fewer controls and a minimum of new distribution lines. Upon completion, the microgrid would include several critical and important municipal facilities including the water pumping station and fire station, the largest employer in the area, and upwards of one hundred residences. In addition to the wide benefits in islanded operation, grid connected operation of the 3.5 MW CHP will support voltage regulation on the NYSEG system, which residents indicated was occasionally problematic. Chateaugay is one of the rare NY Prize projects proposed for a rural, relatively lower income area that is large enough and with the appropriate characteristics to be financially viable.

Chateaugay was also unique with respect to the level of involvement of the main industrial facility in the community, McCadam Cheese. The Project Team maintained close contact with both the plant manager and facilities manager as well as with individuals in the parent company, Agri-Mark, as the study developed. Agri-Mark representatives were able to provide key contact information for their natural gas supply and distribution vendors, allowing the Project Team a more holistic understanding of the natural gas environment in Chateaugay. This was particularly important in Chateaugay as the local gas distribution line was only recently constructed and the tariff structure is somewhat non-standard. It also allowed the Project Team to gain notional support from the local gas distribution utility, St. Lawrence Gas, an important consideration given the relatively large demand of the proposed generator relative to the overall existing gas demand in the community.

Active involvement and attractive infrastructure does not mitigate all issues, however. In Chateaugay, there is abundant hydropower on the nearby rivers and a biomass facility in moderate proximity to the footprint. The complication in connecting these otherwise useful generation assets is multiple. First, the distance between the dams and biomass plant and any given set of critical facilities may be significant; in Chateaugay it is several miles. Traversing this distance to energize the critical facilities and microgrid requires either dedicated distribution lines between the generator and the microgrid, at a cost of several million dollars, or the pick-up of all intermediate loads and the associated isolation switches. For a microgrid with the relatively small scale of the Chateaugay proposal, both options are simply infeasible from a cost perspective. The larger the microgrid footprint becomes, the less redundant and resilient it is. The second issue in connecting the hydropower facilities is the potentially incongruent voltage in the generator connected feeders and the feeders upon with the microgrid is proposed. This voltage step down would require transformers that further add to the cost, and coupled with the distance, render them infeasible.

In comparison to working with a municipal utility, working with the investor-owned NYSEG was a more time-intensive process. As a utility with a large footprint, customer base, and T&D network, NYSEG has many issues to manage that require its attention, among which microgrids and NY Prize were just one. However, NYSEG was receptive to the possibility of infrastructure ownership and microgrid operation, and the Project Team appreciates the exceptionally open dialogue. A NY Prize Phase II award would require more extensive conversations with NYSEG about their role in a future microgrid on the proposed footprint and how a microgrid might utilize existing infrastructure most efficiently.

5.1.2 Statewide Replicability and Lessons Learned

Through the process of developing deliverables for multiple communities over several months, the Team has discovered and considered new questions surrounding microgrid development. These questions address technical viability, financial structures, policy considerations, and other constraints that could inhibit the development or expansion of microgrids in New York State.

Technical. The existing electrical and natural gas infrastructure in a community is the chief determinant of what is possible. Chateaugay has sufficient natural gas availability to support natural gas-fired generation within the microgrid, and the electrical infrastructure is conducive to project development. The unique feature of the electrical system is the community has only a single feeder, and the project proposed to pick up all loads on one side of it. While AMI would allow a more replicable design, the currently proposed design would work well in any rural community with a simple electrical system, a natural gas supply, and a sufficient thermal load. There are no features of the electrical system or the project design that are particular to this community as to prevent replication elsewhere.

Second, the availability of natural gas infrastructure is a major contributor to positive project feasibility. In communities without natural gas, generation is typically limited to solar PV and the tie in of existing diesel backup generation, given the high costs of storage and biomass and the larger footprints required for wind. Given the intermittency of solar, and the low capacity factor in New York State (approximately 15%), solar installations of a few hundred kW do not provide reliable generation for an islanded microgrid. In contrast, natural gas-fired generation provides a high reliability baseload, is relatively clean and efficient, and allows for cogenerated steam sales if there is a proximate off-taker. Chateaugay has sufficient natural gas and a large, industrial steam load which supports the inclusion of a CHP unit.

Third, there is an interplay between the technical size of a CHP unit and the business model of the microgrid. While the CHP unit can load follow in island mode, these units operate at peak efficiency when they are run at a constant output. Additionally, sizing the CHP unit is typically done based on either electric load or steam load, but cannot be sized by both. As such, the most economic sizing of the unit and best business model came from sizing the CHP to meet the minimum steam load of McCadam Cheese while running at peak output, and selling electricity to NYSEG on a long term power purchase agreement, rather than operating the CHP unit to load follow the facility's electric load and using steam only as it was generated.

Financial. Across the portfolio of communities managed by the Project Team, natural gas availability and steam off-takers are the leading elements of financially viable projects. Simply, natural gas generation is more cost efficient and provides highly reliable revenue streams through electricity sales, consistency which is unavailable to a PV driven system. Given the currently high cost of battery storage options, it is difficult to make a compelling case for a small solar PV-battery system as a reliable baseload option

Project financial structures are also important to consider. Revenue from these projects is driven almost exclusively by the sale of electricity and, if available, steam; however, the microgrid control components may require a million dollars or more of capital investment. Ownership structures that separate cost drivers from the revenue streams may be difficult propositions, as the microgrid controls owners would have little opportunity to recoup their investment. This is especially true for privately owned microgrids in locations with reliable power supplies where islanding would be infrequent. In these cases, municipal ownership of the generation and infrastructure would be the most effective. The exception is if the entire microgrid can be developed "behind the meter." While it remains to be seen if utilities will allow this to transpire, a fully behind-the-meter solution in an area with moderate to high electricity prices would likely be a more advantageous financial proposition for connected facilities, as well as for generation and controls owners. Moreover, ancillary services have the potential to provide positive revenue for community microgrids; however, they are hard to qualify for because they require high levels of reserve capacity for most programs, and the payments are somewhat small relative to the electricity that could be generated and sold with an at-capacity generator.

Project size is a final determinant of viability. Small projects with only a few hundred kW of generation simple to not have the revenue streams to support the installation and operating costs of an advanced, MCS and SCADA controlled microgrid. While the Project Team has not identified a bright-line at which projects tend to be viable, those under 500 kW of continuous generation will struggle to cover even variable costs. While fuel costs and generator O&M are commensurate with capital costs and generator size, and therefore revenue, microgrid system maintenance costs are fixed at approximately $70,000 and capital costs at $450,000. While these can be absorbed into a large project, they simply cannot be supported with small microgrids.

Policy. State policy does not currently address microgrids in a cohesive or holistic manner, nor have utility programs adequately recognized microgrid operations in their policies. DR is a potentially lucrative revenue stream in New York; however, current policies do not address microgrid DR participation. For instance, interpretations of the existing NYISO DR programs suggest that microgrids could take payments for islanding in times of high demand on the macrogrid. This scenario, while advantageous from a load shedding perspective, would also remove the microgrid connected generation simultaneously, leaving the macrogrid in a net-neutral position vis-a-vis the microgrid. While the nature of DR payments in such situations is not clear, the Project Team suggests explicit guidance from the NYPSC and the various utilities regarding their respective policies. Due to this lack of clarity, DR revenue has generally been excluded from the Project Team's revenue analysis.

Lastly, local community involvement is an important contributor to microgrid design success. Though even the most robust community engagement may not overcome highly unfavorable infrastructure, it is nonetheless imperative for steady forward progress. In Chateaugay, support from the community has been exceptional, both at the local governmental level and across the included facilities. The inclusion of McCadam Cheese is a lynchpin in this proposal; without their steam and electric loads it would be difficult to gain sufficient scale to complete a financially viable project. The staff at the plant and at parent company Agri-Mark have been engaged throughout the process, working with the Project Team to identify siting options on plant land, and providing contacts to the local natural gas distributors and commodity brokers. Collectively, this information allowed the Project Team to provide a more robust and realistic appraisal of the feasibility of a microgrid in Chateaugay.

Scalability. The structure of the electrical infrastructure, defined in the technical lessons learned section above, is a key factor to expansion of the microgrid. At some point of expansion, it becomes necessary to link multiple feeders, and having proximate feeders of the same voltage and connected to desirable facilities is an important criteria. In Chateaugay, there is only a single feeder that bisects the community and the proposal includes most electrical loads south of the feeder. While this requires a fair number of new control components, there is no concern with voltage incongruence nor electrical power flow problems given the relative simplicity of the local system. Scaling the project would likely require incorporating the main feeder line and picking up much of the rest of the community, actions that may not be supported by NYSEG. Moreover, any ability to island for economic purposes would be lost if the microgrid came to include the main feeder, as there are loads beyond that town that must remain energized.

Natural gas availability is a second constraint on local scalability. The Project Team spoke multiple times with St. Lawrence Gas, the natural gas distributor in Chateaugay, to ensure that the existing gas lines have sufficient capacity to feed the proposed generator. There is ample capacity for all currently proposed and existing uses, including the proposed CHP and the

McCadam expansion, and there will be sufficient capacity left for additional natural gas loads at McCadam. The Project Team does not intend to adversely affect any future additions of gas load at McCadam and, therefore, views the scaling of the project as unlikely absent an expansion in the gas line capacity.

5.1.3 Stakeholder Lessons Learned

Developers. Many of the NY Prize project proposals require the Phase III award to achieve positive economics, and several more will remain in the red even with the grant. At this time there is no incentive for developers to participate in the build-out or operation of proposed microgrids that demonstrate negative returns. The potential for developer involvement is highest in communities with relatively high electricity prices and the presence of steam off-takers; these conditions drive project profitability. Moreover, many of the municipalities are interested in part or full ownership of the projects, but either do not have available funds or lose the project economics without the available tax credits and incentives. In these situations, there may be opportunities for developers to leverage the tax benefits through design-build-own-operate arrangements.

Utilities. The Project Team often experienced problems with information flow. The Project Team would request information about feeders, switches, and other infrastructure from the utilities to inform the best possible microgrid design. However, the utilities were often guarded about providing the full data request in the absence of a design proposal, leading to something of a catch-22 in that neither party was able to adequately answer the request of the other without the desired information. These holdups were incrementally resolved to the satisfaction of both the Project Team and the utilities, but gathering data required significantly more time and dialogue than expected. The utilities may have been unprepared for the volume and detail of data requests from the Project Team, and the expected detail of the overall feasibility study may not have been fully communicated to each party.

Investor-owned-utilities in the Project Team's portfolio were generally against allowing a third party operational control of utility-owned infrastructure. This view is understandable, however it engenders a particularly difficult situation if the utility does not support the microgrid development. NYSEG, on the other hand, has indicated a willingness to discuss ownership and operational scenarios in which it retains a strong role; it's neither necessary nor sufficient for a successful microgrid installation, but it reduces many of the operational concerns. In other situations, the microgrid will generally be forced to construct duplicate infrastructure, with is both prohibitively expensive and against the spirit of the NY Prize. In general, utilities which support the integration of their infrastructure to the extent technically possible allow for more expansive microgrid possibilities.

Academics. Academic considerations in microgrid development may center around three areas. First, research into a relatively small grid systems with multiple generators (some spinning, some inverter-based), temporally and spatially variable loads, and multidirectional power flows may inform better designs and more efficient placement of generation and controls relative to loads.

The second is optimizing financial structures for collections of distributed energy resources and control infrastructure. To-date, most microgrids in the United Stated have been campus-style developments in which the grid serves a single institution and can be easily segregated from the macrogrid. Community microgrids consisting of multi-party owned facilities and generation are a new concept, and literature on how best to own and operate such developments is not yet robust. Lastly, and related to financial structures, is the idea of how a "grid of grids" would be managed and structured to provide optimal operational support and the right mix of incentives to encourage customer and utility buy-in.

Communities. Engaged communities are important, but so too are realistic expectations of what a microgrid might include. Many communities expected dozens of facilities, or entire towns, to be included in the microgrid without understanding the limitations of the electrical and gas systems, the utility's operation requirements, or simple cost feasibility. While the Project Team worked with each community to scope out and incrementally refine the facilities for inclusion, there is still much work to be done communicating the infrastructural realities of microgrid development. Setting expectations ahead of future microgrid initiatives will help communities begin with more concise and actionable goals for their community microgrids.

NYSERDA. NYSERDA awarded 83 Phase I feasibility studies, providing a wide canvas for jumpstarting microgrid development in the state but also placing administrative burdens on the utilities and on NYSERDA itself. As NYSERDA is aware, the timelines for receiving information from utilities were significantly delayed compared to what was originally intended, and this has impacted the ability of the Project Team to provide deliverables to NYSERDA on the original schedule. As mentioned in the Utilities Lessons Learned above, better communication between the State and the utilities may have preemptively alleviated this bottleneck.

Second, microgrid control infrastructure is expensive, and distributed energy resources require some scale to become revenue positive enough to subsidize the controls. Therefore, many NY Prize project proposals are not financially feasible without the NY Prize and myriad other rebate and incentive programs. In practical terms, this means that, while the NY Prize will create a body of knowledge around the development of community microgrids that did not previously exist, it is unlikely to spur unbridled growth of community microgrids in the State without policy changes. This is especially true in regions with relatively low electricity costs and as well as power supply and reliability problems. Additionally, many communities that require improvements to the grid for reliability and resiliency and are lower income communities, which creates the added challenge of making them harder to pencil out financially as the community cannot afford to pay extra to ensure reliability. The projects with the least advantageous financials are often those needed most by the community. This gap is not easily bridged without further subsidization from the State.

5.2 Benefits Analysis

This section describes the benefits to stakeholders associated with the project. The microgrid will provide more resilient energy service, lower peaking emissions, ensure critical and important facilities remain operational during grid outages, and support the goals of New York's REV.

5.2.1 Environmental Benefits

New York State's normal energy portfolio is very clean, with primary energy sources being hydropower and nuclear. Therefore, having a microgrid powered by a natural gas-fired reciprocating generator will increase the overall emissions per kWh. However, the natural gas generator is cleaner than many peaking assets, which come online when statewide demand is high. In particular, microgrid generation will offset diesel backup generators in many locations, reducing diesel fuel burn and overall emissions. The proposed microgrid also offers a platform for expanding renewable generation in the future. The microgrid's generation assets will not exceed current New York State emissions limits for generators of their size and will not need to purchase emissions permits to operate.

5.2.2 Benefits to the Town of Chateaugay

Critical and important facilities in the Town of Chateaugay will receive resilient backup power from the proposed generation assets, ensuring they are available in outage situations and reducing the need for further investments in backup generation. The electricity generated with the solar PV arrays and the natural gas-fired reciprocating generator will also offset higher-emission peaking assets during peak demand events. The Project Team continues to have ongoing conversations with the community and provided a formal summary of the project and next steps in person in Chateaugay on February 3, 2016.

5.2.3 Benefits to Residents in and around Chateaugay

Residents of Chateaugay and the surrounding community stand to gain from access to a broad range of critical services anytime the microgrid is forced into islanded operation by an outage on the grid. Even if they are not formally connected to the microgrid, all residents of Chateaugay and nearby surrounding communities will have access to healthcare and other services in the event of an outage. In the future, the microgrid could be expanded to connect more facilities.

5.2.4 Benefits to New York State

New York State will benefit from the continued localization of energy resources, reducing load and congestion on the grid. Moreover, the expansion of distributed energy resources will further the goals of REV and provide a more resilient overall grid. A successful implementation of the Chateaugay microgrid will provide a proof of concept for the ownership and operation of a hybrid microgrid with local utility support. In addition, the lessons learned described in Section 5.1 are widely applicable to the further development of REV and future NY Prize efforts into Phase II and III.

5.3 Conclusion and Recommendations

The Project Team has concluded the proposed Chateaugay microgrid is feasible. The microgrid meets all of the NYSERDA required capabilities and most of its preferred capabilities. Major challenges include working with NYSEG regarding the proposed interconnections and new distribution infrastructure, and working with the community to site the natural gas-fired reciprocating generator and solar PV. A failure to address any one of these conditions would make it difficult to develop and operate the microgrid as it is currently proposed. With positive adjudication, the microgrid stands to be a case study in collaborative operation.

The proposed Chateaugay microgrid is replicable and scalable, and it provides a proof of concept for a natural gas-driven microgrid in a small community. If successful, it will be a source of new operational information gleaned in operating a true community microgrid within the context of investor owned utility infrastructure and control systems. While the Project Team expects hiccups, there is significant value for NYSEG as a distributed system platform operator if a critical mass of microgrids can be established within their footprint.

This microgrid project will also help accelerate New York State's transition from traditional utility models to newer and smarter distributed technologies, and it will help achieve the REV goals of creating an overall more resilient grid, reducing load and congestion, expanding distributed energy resources, reducing GHG emissions, and constructing more renewable resources. It will also encourage citizens within the community to invest and get involved in local energy generation and distribution and will foster greater awareness of these issues.

Finally, the project will demonstrate the widely distributed benefits of microgrids paired with DER assets. The utility will see improved grid performance, the community will reap the positive benefits of living in and around the microgrid, and industrial customers will benefit from the value of avoided outages. For these reasons, the Project Team recommends this project be considered for continued participation in the NYSERDA New York Prize Community Microgrid Competition.

Appendix

The Project Team obtained monthly metering data for the McCadam Cheese Company and DPW complex from NYSEG and estimated monthly data for other facilities. The following 24 hour load curves represent simulations based on facility type and estimated monthly load factor (ratio of peak to average demand). They are included in this feasibility study to show which facilities have highest and lowest load demands at different times of the day. Analyzing these load demand curves has allowed the team to develop a better overall understanding of the generation capacity needed to sustain the microgrid.

REDACTED PER NDA WITH NYSEG