52 - Town of Moreau

June 2016

Notice

Town of Moreau Microgrid Feasibility Study

Microgrid Project Results and Final Written Documentation

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Date Submitted: April 4, 2016

Contract Number: 63937, Task 5

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Abstract

Together with the Town of Moreau (Moreau), 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 are analyzed and detailed in this document. The Moreau microgrid project faces the challenge of high capital costs and commercial feasibility depends on NY Prize Phase III funding and additional subsidy. The microgrid design incorporates both new and existing distributed energy resources (DER), including an existing solar photovoltaic (PV) array, two existing backup generators, a new 300 kW natural gas fired reciprocating generator, and a new 100 kW solar PV array. This portfolio of DERs will provide reliable, low-emission electricity and 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 generation, energy resilience, clean energy, DER, Moreau

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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
DR	Demand Response
DSP	Distributed System Platform
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
LED	Light-Emitting Diode
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

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
QF	Qualifying Facility
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
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 through its New York Prize initiative to conduct a feasibility study of a community microgrid concept in the Town of Moreau. 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 400 kilowatts (kW) of new, clean energy generation capability. The study concludes that the technical design is feasible, but the project financially infeasible.

The Moreau microgrid project will tie together four critical facilities (per NYSERDA's definition), four other important facilities, and a group of residential units into a community microgrid. Table ES-1 lists all the facilities under consideration for the microgrid concept at this time, and Figure ES-1 shows their locations in the Town of Moreau.

Table ES-1. Prospective Microgrid Facilities

Table lists the facilities in the Town of Moreau'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	Town of Moreau Town Clerk's Office	Public*
F2	South Glens Falls Fire Company	Public*
F3	Moreau Family Health	Health*
F4	Wallace Supply Co Inc	Private**
F5	Landmark Motor Inn	Private**
F6	Hess Express Gas Station	Private**
F7	Saratoga County Sheriff's Office	Public*
F8	ANNEX Storage building	Private**
F9	Residential Group	Residential**
	* Critical Facility ** Important Facility	

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 Moreau microgrid. The two maps below show the east and west side of the microgrid separated by approximately 0.6 miles on Reynolds Road. Additional local loads that will be absorbed in the microgrid in addition to the critical facilities are distributed along the north side of Reynolds Road between the Fire Company (F2) and the Landmark Motor Inn (F5).

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

- One existing 30 kW solar PV at the Town Clerk's office
- Two existing 100 kW natural gas backup generators located at the Town Clerk's office and the South Glens Falls Fire Company
- One proposed 300 kW natural gas-fired continuous duty reciprocating generator at the Town Clerk's office and South Glens Falls Fire Company
- One proposed 100 kW solar PV array at the Town Clerk's office and South Glens Falls Fire Company.

The existing and proposed generation assets should have adequate capacity to provide 100% of the electricity requirements of the facilities in .

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 the nameplate capacity of 630 kW, with 500 kW of capacity from spinning generators. Aggregate demand from all facilities proposed within the microgrid footprint averaged 198 kW and never exceeded 523 kW 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 Moreau. 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.

A hybrid ownership model is envisioned for the Moreau microgrid, wherein one special purpose vehicle (SPV) owns the new DERs and National Grid owns the microgrid components / control infrastructure added to their systems for purposes of operational control. The Project Team believes this hybrid model offers the greatest benefits and flexibility to the utility and customer base within the Town.

Given the capital expenditures, it is anticipated that the SPV will be owned by private investors. National Grid will leverage its energy domain expertise to own, operate and maintain the microgrid components and control infrastructure. It is possible for National Grid to also operate the proposed DERs on an operations and maintenance (O&M) contract. Revenues streams from electricity sales will accrue to SPV investors and will cover variable generation costs. In Moreau, 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 $1.2 million as well as yearly operation, maintenance, and fuel costs totaling $177,000 per year. Overall revenue streams from the project are estimated at $170,000 per year and will be captured primarily through the sale of electricity from the 300 kW natural gas-fired reciprocating generator and the 100 kW solar PV array during grid-connected mode. Other revenues from the proposed microgrid will include tax credits and incentives.

The high capital costs and relatively long payback make the investment a difficult one, and the absence of local demand for thermal energy confines revenues to electricity sales. Assuming the SPV will sell electricity to National Grid at their current supply charge, the microgrid will produce negative operating cash flows from year to year. The Moreau microgrid qualifies for relatively few of the available state and federal incentives for DER assets—the NY Sun program may offset 30% of the capital cost of the solar array, but this only amounts to less than 5% of total project cost. As such, it must rely on direct project-generated revenues, NY Prize Phase III funding, and operating subsidies for its commercial viability.

The Moreau 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 eight critical and important facilities, as well as a residential group, is a significant addition to the resilience of the Town in times of emergency and extended grid outages.

1. Introduction

The Town of Moreau 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 Moreau and National Grid, a team from Booz Allen Hamilton (hereafter Booz Allen or the Project Team) designed a preliminary microgrid concept that will connect eight critical and important facilities and a residential complex with two new generation assets, an existing solar PV array, and two existing backup generators. The design proposes a new 300 kW natural gas-fired reciprocating generator and a new 100 kW solar PV array, both located near the Town Clerk's building and South Glens Falls Fire Company (see Figure EW-1). 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 Moreau and its residents seek to improve the resilience of energy service and lower their environmental footprint.

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

Moreau faces several challenges that could be resolved with the addition of a community microgrid:

- Several key services in the Town have access to emergency back-up generation, but this back-up generation is 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 natural gas generators with solar PV arrays (assuming the existing natural gas pipeline remains intact there will be a continuous supply of natural gas).
- Electricity service in the region has occasionally been interrupted by extreme weather events such as winter storms. For example, several homes, schools, and traffic signals experienced persistent outages throughout the winter of 2014. A microgrid could provide

electricity to critical facilities during extreme weather events, and 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 resource technologies, increasing the viability of natural gas-fired reciprocating generators or solar arrays.

The proposed natural gas-fired DER will provide essential reliability to the Moreau microgrid. Natural gas emits significantly less GHGs per unit of energy than diesel or fuel oil, the typical fuel sources for backup generators, and is currently more cost-effective than combined solar and storage systems. The reciprocating generator will improve energy resiliency in Moreau and will lessen the strain on the local electricity T&D network by reducing the need for power imports during peak demand events. The proposed solar array will help offset emissions from fossil fuel-based DERs 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) 63937 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

Table lists NYSERDA's required and preferred capabilities and annotations of whether or not the Moreau 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
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 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

Capability	Required/ Preferred	Microgrid will meet (Y/N)
Energy storage	Preferred	N
Active network control system	Preferred*	Y
Demand response	Preferred	Y[1]
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.**		

The following section demonstrates how the design concept meets the required capabilities and select preferred capabilities provided by NYSERDA.

2.2.1 Serving Multiple, Physically Separated Critical Facilities

At this stage of the study, the Town of Moreau and the Booz Allen team have identified eight facilities and a group of residential units that will be connected to the microgrid. Four of the connected facilities will provide NYSERDA-defined critical services to the community in the case of an outage. See Table 2 for a full list of prospective facilities to be tied into the microgrid.

Table 2. Town of Moreau Critical and Important Facilities

Table lists critical and important facilities, their addresses, and their classifications as critical or important.

Name of Facility	Address	Classification (Critical, Important)
Town of Moreau Town Clerk's Office	351 Reynolds Rd	Critical
South Glens Falls Fire Company	Reynolds Road	Critical
Moreau Family Health	1448 US Route 9	Critical
Wallace Supply Co, Inc.	1434 US Route 9	Important
Landmark Motor Inn	1418 US Route 9	Important
Hess Express Gas Station	411 Reynolds Rd	Important
Saratoga County Sheriff's Office	353 Reynolds Road	Critical
ANNEX Storage building	349 Reynolds Road	Important
Residential Group	Reynolds Road	Important

[1] The microgrid could participate in Demand Response programs by increasing output from backup natural gas generators, but will not intentionally enter island mode unless there is a forecasted disturbance or outage. See Section 2.2.22 for further details.

The proposed microgrid footprint occupies approximately 100 acres in Moreau. Loads will be interconnected via existing medium voltage National Grid power lines along Saratoga Road (US Route 9) and Reynolds Road. Distributed microgrid equipment and control software will communicate over National Grid'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

Moreau has established a preference for the local hydroelectric dams to serve as the primary energy source for the community microgrid. However, these dams are quite far away from the proposed microgrid coverage area and are connected to different feeder lines. Connecting these dams to the proposed loads is therefore unrealistic within the scope of the NY Prize project.

The Project Team also evaluated the possibility of using solar energy as the primary energy source, but solar arrays do not provide the reliability required in a community microgrid 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 reciprocating generator is the most cost effective way to guarantee the microgrid's energy supply in island mode. As a comparatively low-emission, highly reliable fuel, natural gas is an ideal source of energy for a community microgrid.

The microgrid control system (MCS) will maximize deployment of energy from the solar arrays whenever it is available, and will meet remaining facility demand with electricity from the reciprocating generator. Backup natural gas generators will only come on-line in island mode when other assets cannot meet aggregate facility demand.

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. The control system is capable of automatic load shedding, but the design does not include distributed switches to accommodate real-time shedding of non-critical microgrid loads.[2] The average aggregate microgrid load was 198 kW in 2014, and proposed generation assets are sized so that load shedding in island mode will 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 National Grid's macrogrid when economic and technical conditions align.

[2] Proposed generation assets will maintain system stability and can reliably meet aggregate peak demand, so load-shedding capability is not strictly necessary for the Moreau microgrid. The Project Team determined that energizing all loads in the microgrid coverage area is feasible.

The reciprocating generator and solar arrays will operate continuously in grid-connected mode, reducing local dependence on grid-supplied power. The backup spinning generators will come on-line in island mode as necessary to meet critical loads. The spinning generators have 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 Moreau microgrid switches to island mode, it will disconnect all downstream non-microgrid loads that normally receive power from the Butler Sub 362 feeder. This means that the microgrid will not switch to islanded mode to participate in demand response (DR) programs. Intentional island mode will only be utilized in forecasted grid outage scenarios.

2.2.5 Resynchronization to National Grid Power

When operating in island mode, the automated switch at the point of common coupling (PCC) will automatically monitor frequency, voltage, and current, and will re-sync based on those variables. Signals from the MCS will prompt re-connection when monitored operational variables on the larger grid 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 US Route 9 (Saratoga Road) to serve as the PCC between the microgrid and National Grid'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 3 outlines the most significant state interconnection standards that apply to this microgrid project. Customers that wish to connect DER projects to National Grid's system must follow the same New York State Standard Interconnection Requirements identified in Table 3.

Table 3. New York State Interconnection Standards

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

Standard Category	Description
Common	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
	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
	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
	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
	The required operating range for the generators shall be from 88% to 110% of nominal voltage magnitude
	The required operating range for the generators shall be from 59.3 Hz to 60.5 Hz
Synchronous Generators	Requires synchronizing facilities, including automatic synchronizing equipment or manual synchronizing with relay supervision, voltage regulator, and power factor control
	Sufficient reactive power capability shall be provided by the generator-owner to withstand normal voltage changes on the utility's system
	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
	Adopt one of the following grounding methods: • Solid grounding • High- or low-resistance grounding • High- or low-reactance grounding • Ground fault neutralizer grounding
Induction Generators	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
Source: NYS Standardized Interconnection Requirements and Application Process, NYS PSC	

2.2.7 24/7 Operation Capability

The project concept envisions a reciprocating natural gas-fired generator as the microgrid's main generation source (the solar arrays 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 natural gas generators at the Town Clerk's Office and Fire 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 Moreau. The new automation solution proposed in this document will serve as a protocol converter to send and receive all data available to the operator over National Grid'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 rotating as well as inverter based energy sources) with the exception of the existing 30 kW solar PV array. The 30 kW array will not have a significant impact on power stability or synchronization. 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.

2.2.10Load Following and Frequency and Voltage Stability When Islanded

The microgrid's control scheme in island mode is similar to that of the larger transmission system that 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 Moreau microgrid will not be able to disconnect entire loads 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 in microgrid design process 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. For example, small generators operating in island mode do not have the inertia of larger systems, and as such the microgrid controls and any possible load shedding will have to be monitored and dispatched in close concert.

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 and/or digital electronics-based loads may be less reliable because these loads can negatively affect power quality and stability. The Moreau microgrid will connect four commercial facilities, three local government buildings, a healthcare center, and a group of residential units. No individual facility will have a significant negative impact on local power quality. The approximate load breakdown by sector for the Moreau microgrid is as follows:[3]

- Health – 3% of load
- Public – 26% of load
- Private – 61% of load

[3] Estimated based on each facility's typical 24 hour load profile from 2014.

- Residential – 9% of load

The Landmark Motor Inn and Wallace Supply Co, Inc. account for approximately 57% of the microgrid's potential peak electricity demand. Targeted energy efficiency (EE) upgrades at either of these facilities 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 Moreau is exposed to the normal range of weather conditions that affects 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. The Town of Moreau experienced several significant disruptions to power service during hurricanes Irene and Lee and Superstorm Sandy. 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. At minimum, the new natural gas reciprocating generator (the microgrid's main generation asset) will be constructed within an enclosure on the Fire Company's land and will therefore be protected from extreme weather. The existing backup generators are similarly enclosed. The solar arrays will not produce energy during extreme weather events, but the microgrid's spinning generators should 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 Moreau 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 natural gas reciprocating generator will be equipped with black-start capabilities. If the Moreau grid unexpectedly loses power, the microgrid control system will initiate island mode by orchestrating the predefined black start sequence. The reciprocating generator will require an auxiliary source of DC power to start multiple times in case of failure. The generator will ramp up to 60 hertz (Hz) and prepare to supply each of the microgrid loads in sequence. The MCS will bring back-up generators on-line and synchronize their output as necessary. After the spinning generators have established a stable power supply, the MCS will synchronize output from the 100 kW solar PV array and bring it on-line. The 30 kW solar PV array is too small to impact power quality or synchronization, and therefore will operate continuously throughout the black start sequence.

2.2.14 Energy Efficiency Upgrades

Energy efficiency is critical to the overall microgrid concept. Several facilities in Moreau have invested in significant EE upgrades. For example, the new Town Hall (Town Clerk's Office) building was designed and constructed with EE in mind. The South Glens Falls Fire Company also recently re-built their headquarters and included several EE designs and devices.

Although the community has had success in reducing local energy use, there is still potential for EE upgrades in Moreau at the commercial facilities within the footprint. Two facilities, Wallace Supply Co, Inc. and the Landmark Motor Inn, currently use 52% of microgrid electricity (57% of peak demand). The Project Team was unable to obtain information on the specific EE upgrades required at these facilities, but both will likely qualify for incentive programs offered by National Grid and NYSERDA. The Project Team estimates the reduction potential for the eight included facilities and residential complex to be approximately 40 kW.

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. The Project Team believes this is a required capability.

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. The Project Team believes this is a required capability.

2.2.18 Smart Meters

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

2.2.19 Distribution Automation

The automation solution outlined in this study for Moreau'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). The Project Team believes this is a required capability.

2.2.20 Energy Storage

At this time, the cost of battery storage is prohibitively high for integration into the Moreau microgrid. Despite this, the MCS will be capable of fully utilizing and optimizing storage resources—including charging and discharging cycles for peak demand shaving—in case the town re-evaluates 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.[4]

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 project's fiber optics backbone partitioned using gigabit Ethernet switches. The Project Team believes this is a required capability.

2.2.22 Demand Response

The Moreau microgrid will not intentionally switch to island mode to participate in DR programs because doing so will disconnect all downstream loads on the Butler Sub 362 feeder. The microgrid's participation in DR programs will therefore be limited to curtailing flexible loads and ramping up generation from the reciprocating generator and/or the existing natural gas generators. However, 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

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

available. Participation in DR programs will likely be limited to voluntary participation when capacity is available.

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, 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

As recommended by National Grid, the proposed community microgrid is fairly small, with an average load of only 198 kW. If the microgrid owners negotiate a long-term power purchase agreement (PPA) with National Grid, the Project Team expects the generators to run continuously throughout the year. However, if the NYPSC designates community microgrids as Qualifying Facilities (QF), project owners can take energy sales behind the meter and generation assets will be configured to follow aggregate load (without exporting excess energy). The MCS will fully utilize the optimum output of generation sources at the lowest cost in a unique 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 O&M cost. In some rare situations, the 100 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 MCS will fully integrate and optimize output from the proposed solar arrays at Moreau Healthcare and the Town Hall complex.

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 Moreau 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 Moreau's main substation into the broader National Grid transmission system. If allowed, the microgrid will sell excess energy from the solar arrays and reciprocating generator to National Grid.

Most lucrative NYISO ancillary service markets, such as the frequency regulation market require participants to bid at least 1 megawatt (MW) of capacity. The microgrid's generation assets have an aggregate nameplate capacity of 630 kW, so participation in these ancillary service markets will not be possible from a regulatory standpoint. Other ancillary service markets, such as spinning and non-spinning reserves, do not provide competitive payments to small-scale generators such as the microgrid's 300 kW reciprocating generator. The Project Team has concluded the microgrid most likely will not participate in NYISO ancillary service markets unless project owners overbuild generation assets which is not recommended at this time.

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. With one extra MW of electricity capacity, the microgrid could also participate in the novel NYISO Behind the Meter: Net Generation program. 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 can also display historical trends in system conditions and process variables.

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 reciprocating generator and solar arrays, and sale of energy under a custom long-term Power Purchase Agreement with National Grid. Investors will receive revenue from electricity sales and possibly from participation in ancillary service or DR programs. More detail is provided in Section 3.5.2.

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 3.2.6.

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 3.2.6.

2.3 Distributed Energy Resources Characterization (Sub Task 2.3)

As described above, the Moreau microgrid design includes 500 kW of spinning generation and 130 kW of solar energy capacity. 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

The Moreau microgrid will incorporate the existing natural gas backup generator and solar array at the Town Clerk's Office as well as the existing natural gas backup generator at the Fire Company (see Table 4 for details on existing generation assets). The solar array will stay on-line throughout the year, whereas the natural gas generators will only come on-line to provide supplemental power as necessary in island mode. Microgrid owners may be able to bid capacity from the backup generators into the NYISO Special Case Resources (SCR) program or run the generators on an *ad hoc* basis during National Grid demand response events.

Most existing generators require additional components to be integrated into the microgrid control scheme. The natural gas backup generators will be outfitted with grid paralleling switchgear and controllers to regulate and synchronize their output. The existing solar array will not be outfitted with grid paralleling switchgear or controllers because it is relatively small and its output will have relatively little effect on power stability in island mode.[5] The solar array's existing inverter and internal breaker will allow it to operate as part of the microgrid in grid-connected and islanded mode, but the MCS will not be able to regulate its output.

The natural gas backup generators will only be activated to supplement power from the solar arrays and reciprocating generator in island mode or to participate in demand response programs.

[5] The Project Team's engineers determined that the 30 kW solar array was too small to merit interconnection. However, if National Grid requires *additional* grid paralleling controllers and switchgear.

Table 4. Existing Distributed Energy Resources

Table describes the existing DERs to be incorporated into the microgrid, including description, fuel source, capacity, and address.

Name	Description	Fuel Source	Capacity (kW)	Address
DER1	Existing Solar Panel	Sun	30	351 Reynolds Rd
DER2	Existing Natural Gas Generator	Natural Gas	100	351 Reynolds Rd
DER3	Existing Natural Gas Generator	Natural Gas	100	Reynolds Road (at the Fire Department)

2.3.2 Proposed Generation Assets

The microgrid design includes two new generation assets: a 300 kW natural gas-fired continuous duty reciprocating generator and a 100 kW solar PV array, as shown in Table 5. The solar array will be constructed in the open field behind the Town Clerk's Office, while the reciprocating generator will be located behind the Fire Company on land owned by the Town. Existing natural gas infrastructure in Moreau can support continuous operation of the reciprocating generator.

Table 5. Proposed Generation Assets

Table shows the rating, fuel, and address for proposed generation assets.

Name	Technology	Rating (kW)	Fuel	Address
DER4	New Natural Gas Generator	Natural Gas	300	351 Reynolds Road
DER5	Solar Panel	Sun	100	351 Reynolds Road

The design proposes a 300 kW reciprocating generator because both the electrical and thermal loads in Moreau are relatively small. The electric load is not nearly large enough to sustain a combined cycle turbine with a heat recovery system, and there is no adequate thermal offtaker to merit addition of combined heat and power (CHP) capability. The Project Team analyzed the benefits and costs of several generator technologies and found that a small scale reciprocating natural gas generator provided the best combination of energy resiliency, cost, and efficiency.

2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics

The proposed design provides Moreau with several additional energy resources. In grid-connected mode, the 300 kW reciprocating generator and solar arrays will operate in parallel with the main grid, which, based on the proposed business model of signing a long term PPA with the distribution utility would essentially mean exporting excess power when generation exceeds demand and importing power from the larger grid to meet peak demand when necessary. In islanded mode, the microgrid control system will first deploy energy from the proposed reciprocating generator and solar arrays, and then bring backup generators on-line as necessary. The proposed reciprocating generator is sized so that spinning generators can meet the entire microgrid load (so long as aggregate load does not exceed the 2014 peak demand). In general, peak demand is coincident with the peak output of solar units. Therefore, the combination of spinning generators and the solar arrays will be sufficient to meet peak demand of the microgrid absent significant load growth.

Although the team is still determining the best way to protect the generator from weather, the design will ensure it is safe from rain, snow, strong winds, or falling trees. At minimum, the new natural gas reciprocating generator will be placed in an enclosure on the Town's land. The existing natural gas pipeline is buried to protect it from severe weather.

The microgrid's information technology 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 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 Moreau 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 natural gas reciprocating generator and existing backup generators will be capable of supplying reliable electricity by providing:

- Automatic load following capability – generation units and controls 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 generators will have auxiliary power (batteries) required to start and establish island mode grid frequency. After the reciprocating generator has established stable power flow, the main microgrid controller will synchronize the solar array inverters to match the reciprocating generator's frequency and phase.
- Conformance with New York State Interconnection Standards,[6] described in Table 3.

2.4 Load Characterization (Sub Task 2.2)

The Project Team sized proposed DERs according to electricity demand data from the load points within the proposed footprint. The load characterizations below describe the electrical loads served by the microgrid.[7] Descriptions of the loads to be served by the microgrid along with redundancy opportunities to account for downtime are included below. None of the connected facilities have sufficient thermal energy demand to merit the addition of combined heat and power capability to the proposed reciprocating generator.

[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] Estimated loads are based on metering data from the facility's account numbers via National Grid's on-line database.

2.4.1 Electrical Load

The Project Team evaluated eight primary electrical loads and one residential complex for the Moreau microgrid (see Table 6 for a list of microgrid facilities). For aggregate weekly, monthly, and yearly energy consumption as well as average and peak power demand, see Table 2. For a cumulative 24 hour load profile, see Figure 2. Typical 24 hour load profiles for each facility can be found in the Appendix.

Moreau's proposed community microgrid will incorporate a healthcare facility, the local government office, a fire department, and a gas station, all within close proximity to the primary National Grid feeder on Reynolds Road and Saratoga Road (U.S. Route 9).

Table 6. Town of Moreau List of Prospective Microgrid Facilities

List of potential microgrid facilities, including their addresses, reference key for Figure ES-1, and classifications.

Map	Property	Address	Classification
F1	**Town of Moreau Town Clerk's Office**	351 Reynolds Rd	Public
F2	**South Glens Falls Fire Company**	Reynolds Road	Public
F3	**Moreau Family Health**	1448 US Route 9	Health
F4	**Wallace Supply Co, Inc.**	1434 US Route 9	Private
F5	**Landmark Motor Inn**	1418 US Route 9	Private
F6	**Hess Express Gas Station**	411 Reynolds Rd	Private
F7	**Saratoga County Sheriff's Office**	353 Reynolds Road	Public
F8	**ANNEX Storage building**	349 Reynolds Road	Private
F9	**Residential Group**	Reynolds Road	Residential

The microgrid design does not require new electrical distribution lines to isolate facilities on their own network. However, the microgrid will require several new automated isolation switches along existing National Grid feeders and new equipment to connect each generator to the microgrid's electrical and communication systems. Two fuses on Reynolds Road will stop current from the generators from flowing to the larger grid if they become overloaded. Figure 1 provides an illustration of the proposed microgrid design and layout, including loads, switches, existing electrical infrastructure, and proposed electrical infrastructure. For a more detailed representation of the proposed electrical infrastructure, refer to Figure 3 (one-line diagram).

Figure 1. Moreau 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. Pictures are separated by approximately 900 feet (second image is directly south of top image).

National Grid provided the Project Team with twelve months of metering data for connected facilities (January through December of 2014), summarized in Table 7. The aggregate peak load in 2014 was 523 kW, and the monthly average was 198 kW.

Table 7. Moreau's 2014 Microgrid Load Points

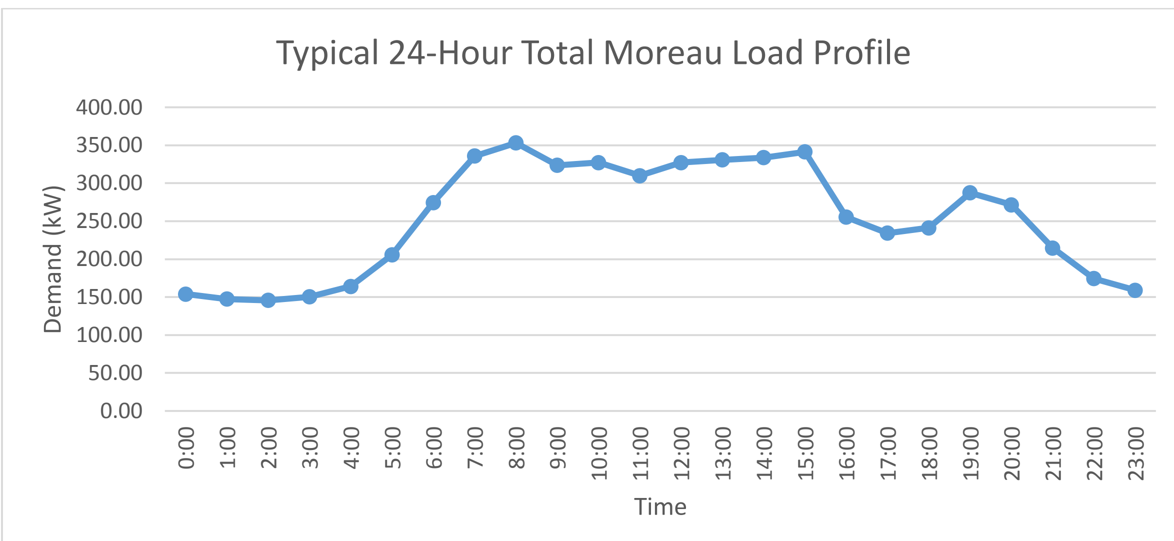
Table shows the microgrid electric demand in kW, electric consumption in kWh, and thermal consumption in MMBTU.

	Electric Demand (kW)		Electric Consumption (kWh)			Thermal Consumption (MMBTU)[8]		
	2014 Peak	2014 Monthly Average	2014 Annual	2014 Monthly Average	2014 Weekly Average	2014 Annual	2014 Monthly Average	2014 Weekly Average
Microgrid Loads	523	198	1,738,075	144,840	33,684	124	10	2

Figure 2 provides a typical aggregate hourly load profile for the Moreau microgrid. Aggregate demand sharply increases around dawn and stays high until around 15:00, at which point demand dips slightly, rises slightly, and returns to the night-time baseline.

Figure 2. Typical 24-Hour Cumulative Load Profile

Figure illustrates the typical 24-hour cumulative load profile for connected facilities. The figure represents the sum of individual typical 24-hour load profiles.



[8] Despite the thermal load indicated in this table, thermal consumption in Moreau is predominantly heating. It is performed by a system or systems which cannot be replaced by a CHP unit. None of the thermal off-takers can support a CHP facility in Moreau.

The 300 kW reciprocating generator and solar arrays will operate continuously in both grid-connected and islanded mode. Although the solar arrays will not operate at full capacity throughout the year, they will typically be most productive when facility demand is highest.

When the solar arrays are operating close to their maximum production points, the microgrid's generation capacity will approach the nameplate capacity of 630 kW, with a guaranteed 500 kW from spinning generators. Aggregate demand from microgrid facilities averaged 198 kW and never exceeded 523 kW in 2014.[9] 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. Microgrid facilities can mitigate this threat 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.

Because the microgrid design does not rely on one primary generation asset, but rather includes five different generation assets, each asset should have downtime available at various points throughout the year. This will provide valuable redundancy when generators need to be taken offline for maintenance.

2.4.2 Thermal Consumption

The Project Team conducted an extensive study on connected facilities to determine whether the design could include a CHP unit, which revealed that the connected facilities do not have sufficient thermal energy demand to merit addition of CHP capability.

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 new 300 kW natural gas-fired reciprocating engine, new 100 kW solar PV array, and existing 30 kW solar PV array will operate continuously, supplying energy to microgrid-connected facilities and potentially exporting excess energy to the larger National Grid system. The Moreau microgrid

[9] This estimate was calculated by summing each facility's peak demand from 2014 and therefore assumes that all facilities reached peak demand at the same time, which is unlikely. The true peak demand was almost certainly less than 523 kW, but the Project Team was unable to obtain synchronized real-time load data for all included facilities.

will incorporate three existing generation assets: a 30 kW solar PV array (as mentioned above), a 100 kW natural gas backup generator at the Town Clerk's Office, and a 100 kW natural gas backup generator at the South Glen Falls Fire Company (hereafter the Fire Company). The backup generators will not operate in grid-connected mode, but will come on-line as necessary to supplement power in island mode.

If the larger grid experiences a power emergency while the microgrid is connected, the microgrid 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. If the 300 kW reciprocating generator has sufficient capacity, it will ramp up generation as necessary to fulfill the necessary power requirement. If the 300 kW reciprocating generator cannot meet the necessary power requirement, the main microgrid controller may access up to 200 kW of power from the backup natural gas generators.

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 (autonomous) mode (as described in Section 2.7.4). The microgrid will intentionally switch to islanded mode during forecasted National Grid outages or disturbances to maintain electricity supply for microgrid facilities—the MCS will manage the aggregate 500 kW of spinning generation and 130 kW of inverter-based generation from the solar PV arrays to match aggregate demand in real time. Because the output of the solar arrays depends entirely on external factors, the natural gas generators will provide flexible, real-time response.

The microgrid will not intentionally switch to island mode for economic reasons in Moreau (i.e., to participate in DR programs or beat electricity prices on the spot market) because doing so would disconnect downstream facilities from power. Refer to the simplified one-line diagram in Figure 3 for a detailed device representation showing both existing and proposed generation assets, utility interconnection points, and switches that will isolate the microgrid from the local National Grid feeder.

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 point of common coupling, and the proposed utility infrastructure investment are also fully discussed below.

2.6.1 Electrical Infrastructure

The local utility, National Grid, owns the existing electrical infrastructure in the Town of Moreau. The Butler Sub 362 substation is the primary feeder in the area, but there may be additional feeders that can supply the Town with power. If this is the case, National Grid has the option of using another feeder as a redundant secondary supply of electricity. However, this study assumes that the Town can only receive power from the Butler Sub 362 feeder.

The PCC with the National Grid system will be located along the Butler Sub 362 feeder (SW1 in Figure 3). One new automated switch will disconnect the microgrid from this feeder at the PCC. Other isolation switches (SW2-8 in Figure 3) will disconnect non-critical loads that are not part of the identified microgrid footprint, as well as downstream power lines. The existing switch south of the intersection of Saratoga Road and Reynolds Road is manual and must therefore be upgraded to serve its function in the microgrid control scheme. The natural gas generators and 100 kW solar array will require switchgear and controllers to communicate with the microgrid control system; however, the existing 30 kW solar array will not require new switchgear and controllers because its output will have relatively little impact on power stability. To ensure compatibility with the MCS, microgrid owners will need to upgrade the existing switches that connect the two backup natural gas generators to the power supply. See Figure 1 (Equipment Layout) 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 8 to Table 10) describe the microgrid components and are referenced throughout the rest of the document.

Table 8. Moreau Distributed Switches Description

Table outlines all twelve distributed switches with their names (for reference to the equipment layout), descriptions, and status as proposed.

Name	Description	New/Upgrade
SW1	Automatic switch for feeder isolation	New
SW2	Automatic switch for non Microgrid load isolation	New
SW3	Automatic switch for non Microgrid load isolation	New
SW4	Automatic switch for non Microgrid load isolation	New
SW5	Automatic switch for non Microgrid load isolation	Upgrade
SW6	Automatic switch for non Microgrid load isolation	New
SW7	Automatic switch for non Microgrid load isolation	New
SW8	Automatic switch for non Microgrid load isolation	New
SW9	Generator Breaker	Upgrade
SW10	Generator Breaker	New
SW11	Inverter Internal Breaker	Upgrade
SW12	Generator Breaker	Upgrade

Table 9. Moreau's Network Switch Description

Table outlines all eleven 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 4 for communication	Proposed	Refer to Eqp. Layout
NS5	Near Switch 5 for communication	Proposed	Refer to Eqp. Layout
NS6	Near Switch 6 for communication	Proposed	Refer to Eqp. Layout
NS7	Near Switch 7 for communication	Proposed	Refer to Eqp. Layout
NS8	Near Switch 8 for communication	Proposed	Refer to Eqp. Layout
NS9	Near DER 3 and DER 4 for communication	Proposed	Refer to Eqp. Layout
NS10	Near DER 2 and DER 5 for communication	Proposed	Refer to Eqp. Layout
NS11	Near EMS and Workstations for communication	Proposed	Refer to Eqp. Layout

Table 10. Moreau's Server Description

Table describes the workstation and servers, their status as proposed, and their addresses.

Name	Description	Status	Address
Workstation	Operator/Engineer workstation	Proposed	351 Reynolds Rd
Server1	Primary EMS and SCADA	Proposed	351 Reynolds Rd
Server2	Secondary EMS and SCADA	Proposed	351 Reynolds Rd

The National Grid distribution system in Moreau consists of medium voltage lines (13.2 kilovolt (kV)). All branches off these medium voltage lines have their own transformers that step incoming power down to low voltage.

Figure 3. Moreau One-Line Diagram

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

REDACTED PER NDA WITH NATIONAL GRID

2.6.2 Points of Interconnection and Additional Investments in Utility Infrastructure

The PCC between the main grid and the microgrid will be located along the Butler Sub 362 feeder (along US Route 9/Saratoga Road). New automated circuit breakers and switches will be required to isolate the microgrid loads from the local National Grid feeder and downstream loads. New switches will also be required to disconnect each non-microgrid load located between switches 1, 5, and 8 (see Figure 3). Most of the generators connected to the microgrid will require controllers and switchgear to regulate and disconnect output, if necessary. However, the existing 30 kW solar array does not require generation controllers or switchgear, because its output will have little impact on the microgrid's power stability in island mode.

The current microgrid design does not allow for the segmentation of loads—the only internal switch is manual and therefore will not respond to commands from the MCS. However, the MCS will have precise control over generator output and can disconnect any of the generators from the microgrid. The fast ramp rates of the included natural gas generators will allow the MCS to provide voltage and frequency control within the millisecond response intervals required for maintaining a stable microgrid.

Table 11. List of Additional Components

Table lists all proposed microgrid devices/components.

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.
Microgrid Control Center (Siemens MGMS or equivalent)	1	Provides data trending, forecasting, and advanced control of generation, loads and Advanced Metering Infrastructure (AMI)/SCADA interface, interface to NYISO for potential economic dispatch.
Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay or equivalent)	8	Upgraded and new breakers/switches at 8 distribution overhead switches. Isolate the feeder and downstream loads from the microgrid
Generation Controls (OEM CAT, Cummins, etc.) (Load Sharing Woodward or equivalent)	3	Serves as the primary resource for coordinating the paralleling load matching and load sharing of spinning generation.
PV Inverter Controller (OEM Fronius or equivalent)	1	Controls PV output and sends data to MCS for forecasting.
Network Switch (RuggedCom or equivalent)	11	Located at IEDs and controllers for network connection, allowing remote monitoring and control.

All microgrid devices will require a reliable source of direct current (DC) power. Each device (or cluster of devices) will have a primary and backup power supply source. During normal operation, 120 volt alternating current (VAC) power will flow through 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 system protection system senses 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. Protection schemes are currently 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, the microgrid designer will have to perform protection studies accounting for the key characteristics of island mode, which include possible bidirectional power flows and very low currents.

The current design includes controls that can prevent back-feeding of power to the larger National Grid system. However, if selling power in energy or ancillary service markets is allowed, the microgrid is capable of selling excess energy back to National Grid.

2.6.4 Thermal Infrastructure

The proposed natural gas reciprocating generator requires a steady supply of natural gas to operate. The reciprocating generator will utilize existing thermal infrastructure in Moreau for its fuel supply—a 6 inch medium pressure (35 psi) natural gas pipeline currently supplies gas to the existing natural gas generators at the Town Clerk’s Office and Fire Company. The pipeline will not require significant upgrades or extension to provide adequate volume and pressure to the proposed reciprocating generator.

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 or microgrid control system. 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 will synchronize frequency and voltage magnitude with the larger grid and will have the potential to export excess electricity to National Grid. 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 National Grid system (described in Section 2.7.7).

2.7.1 Microgrid Supporting Computer Hardware, Software and Control Components

The following is a preliminary list of hardware components needed for Moreau'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 in the event that building energy management systems are installed or existing manual switches are upgraded to automated switches.
- Microgrid Control System – The MCS is composed of an Energy Management System (EMS) 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.
- Distribution system – The microgrid requires automated switches and breakers to isolate the microgrid from the local feeder and disconnect downstream loads. Other control elements at or near individual loads will allow the MCS to maintain adequate power stability in islanded mode.
- Utility breakers and controls – These automatic controls will interface between the microgrid and the National Grid medium voltage feeder (Butler Sub 362).
- Generator controls/relays – These components will be installed at each generating unit/inverter (except for the 30 kW solar PV array, which is not big enough to have a significant effect on power stability or synchronization). They will control generator output based on signals from the MCS.

The proposed system uses Service Oriented Architecture (SOA) software that serves as the messaging and integration platform for the monitoring and control of distributed equipment. The SOA is vendor-agnostic—it 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:

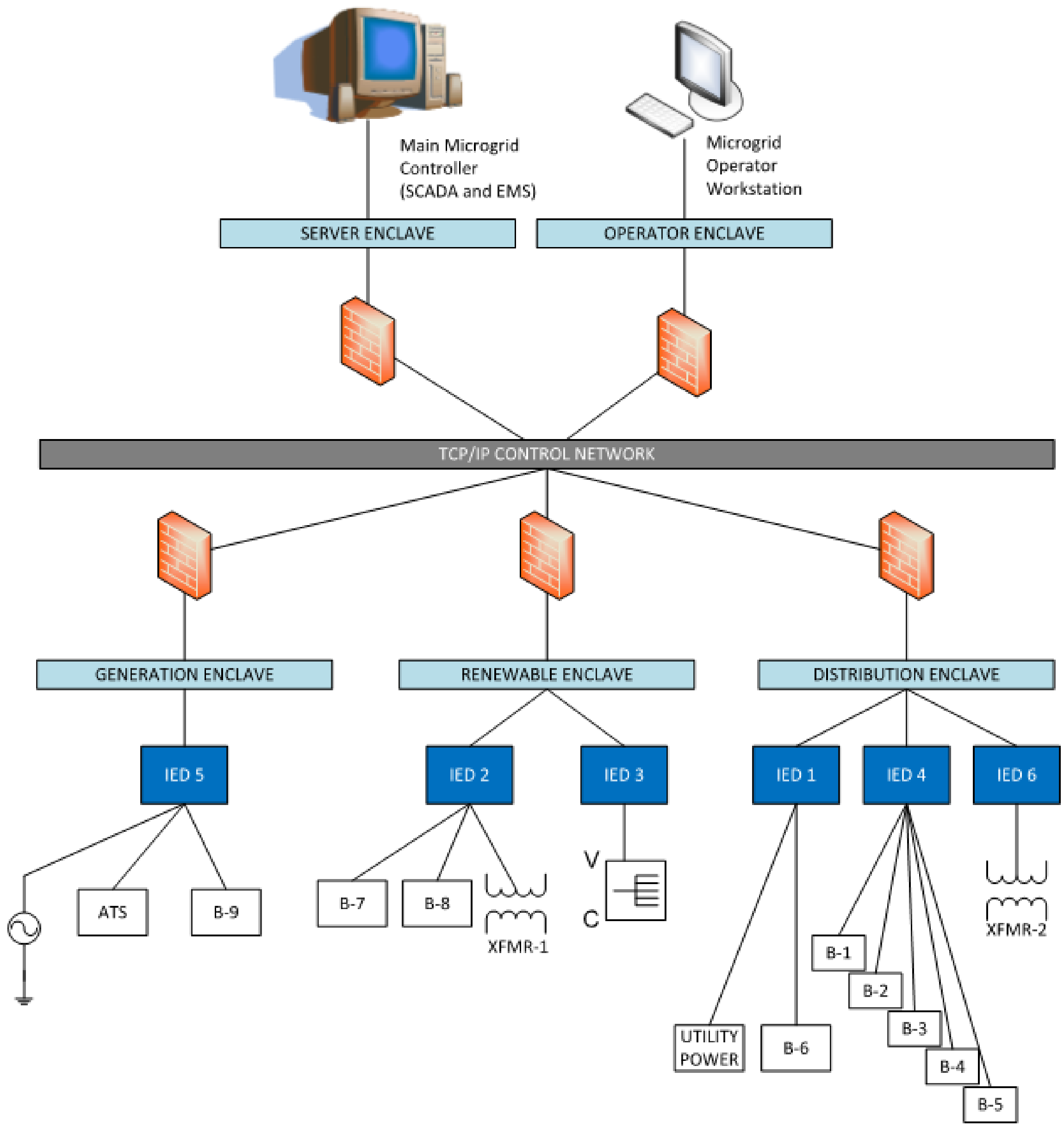
- SOA software platform – The SOA platform facilitates the monitoring and control of included power devices and control systems.
- Two RAID 5 servers (Redundant Array of Independent Disks) (including 1 primary, 1 backup) for the MCS – The MCS will include an EMS and a SCADA-based control center, and 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.
- Application servers (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 (but are not limited to) 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.
- Intelligent Electronic Device Distribution Switches: Automated pole mount circuit breaker/switch (Siemens 7SC80 relay) – The microprocessor based logic controllers, also referred to as IEDs, are located at or near loads and 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.
- PV Inverter Controller (OEM Fronius, etc.) – This component will control output from the 100 kW solar PV array and send data to the MCS for forecasting. The 30 kW solar PV array will not require an inverter controller because its output will not have a significant impact on power stability or synchronization.

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

Figure 4. Diagram of a Typical Microgrid Control System Hierarchy

The following network diagram illustrates a typical 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 Energy Management System server and client workstation node.



A Building Energy Management System is not listed as a NYSERDA-required or preferred capability as defined in this Feasibility Study; however, several of the components that compose a conventional BEMS are already included in the proposed automated microgrid control system (solar PV integration and monitoring and control via smart technologies). As noted, the proposed microgrid is Service Oriented Architecture based. This makes it possible to add building energy control systems (ventilation, lighting, fire, and security) in the future because these components integrate easily using open standards, such as Modbus, LonWorks, DeviceNet, and other Transmission Control Protocol/Internet Protocol internet protocols.

2.7.2 Grid Parallel Mode Control

When the microgrid operates in grid-connected mode, every generator under MCS control 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. 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 rotating generators are capable of providing ancillary services to National Grid’s grid to enhance the reliability of the system. They can provide reactive power and frequency response services on demand, but providing reactive power support may diminish the generators’ ability to generate real power.

Please refer to the **Error! Reference source not found.** in the Appendix for the control scheme sequence of operations.

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 finally execution and real time optimization.

Data logging features will allow the MCS 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 10 minutes or longer), voltage violations (defined as variance of actual voltage to predicted voltage for 5 minutes), and frequency violations (defined as variation to predicted frequency of more than 0.2 Hz for more than 10 minutes). The executive dashboard will calculate daily, weekly, and monthly rolling totals for these metrics.

After analyzing historical trends and monitoring real-time data, the main microgrid controller will optimize microgrid operation by managing generator output and flexible loads. In grid-connected mode, the microgrid control system 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 distribution system or transmission level. 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 applicable switches at the PCC will open automatically disconnecting the microgrid from the larger grid. Any existing online generation will be isolated and ramped down via generation breakers with the exception of the 30 kW solar PV array, which is too small to have a significant effect on this process. 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 reciprocating generator's black-start capabilities (and those of other spinning generators if necessary), the MCS will commence island mode operation. The main generator will ramp up to 60 Hz and prepare to supply each of the microgrid loads in sequence. After the reciprocating generator is on-line and power flow through the microgrid is stable, the MCS will synchronize output from the 100 kW solar array (voltage and frequency) and bring it on-line. In steady state, its phase will be different, similar to grid-connected steady state operation.

The microgrid will intentionally switch to island mode if:

- The National Grid system has an expected outage which could potentially affect transmission power to Moreau substations.
- National Grid needs to perform network maintenance work, thereby isolating loads in the Moreau area.

The intentional transition to island mode begins when the system operator sends the command to prepare for islanding. The control system will automatically start and parallel the generation assets, including spinning backup generators (as necessary). Once output from the available power sources is synchronized, the system is considered ready to implement islanded operation and will begin opening the incoming utility line breakers. Under intentional islanding, the transition to island mode is seamless and closed (it does not require black start).

Please refer to **Error! Reference source not found.** for the control scheme sequence of operation in the Appendix.

2.7.5 Energy Management in Islanded Mode

After completing the transition to island mode, the MCS will perform a series of operational tests to ensure that 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 if additional load can be added. The N+1 strategy ensures 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. Although the MCS will not be capable of disconnecting low-priority loads, it will control generator output in real time to maintain system stability.

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 natural gas generator (or spinning backup generators).
- Loss of power from the solar arrays.

When the microgrid operates in island mode, the generation sources must produce power at the same voltage magnitude and frequency. 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 microgrid control system 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 microgrid controller will first deploy energy from renewable generation assets and adjust output from spinning generators to match remaining electricity demand. The microgrid design relies on fast ramp rates from spinning generators to compensate for changing output from the solar arrays.

Other designs may incorporate battery storage to smooth these rapid fluctuations and ensure a reliable supply of energy when sunlight is not available. However, the Booz Allen Team found the cost of battery storage to be prohibitively high for Moreau's microgrid system. The analysis considered the potential of using storage for three purposes:

- System reliability: short term back-up, 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 storage was not needed to improve system reliability (the fast ramp rates of included spinning generators provide 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 300 kW reciprocating generator will be equipped with black start capabilities. The existing spinning generators in Moreau may also be outfitted with black start capabilities to provide system redundancy in grid outage scenarios. If the Moreau grid unexpectedly loses power, the main microgrid controller will initiate island mode by orchestrating the predefined black start sequence. The microgrid then begins an un-intentional transition to island mode. A DC auxiliary support system is an essential part of each generator's black start capabilities. Each back-up battery system must have enough power to start the generator multiple times.

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 (with the exception of the 30 kW solar PV array, which will not have a significant impact on synchronization or power stability).
3. The main microgrid controller waits a pre-set amount of time (approximately 30 seconds) in case power is restored to the larger grid.
4. The main microgrid controller disconnects the entire current load (after estimating aggregate electricity demand).
5. The microgrid generators 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). If one or more generators do not start as expected during a utility outage, the microgrid control system is equipped with contingency algorithms to appropriately manage the situation. If possible, the control system will still isolate the microgrid.

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

Please refer to the Appendix for the control scheme sequence of operations.

2.7.7 Resynchronization to National Grid 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 power has been reliably restored and then will commence resynchronization with the National Grid power supply. As a final check, the system operator will either receive an automated notification or directly contact National Grid 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 larger grid at the PCC and determine when appropriate levels of current and voltage have been restored. When power is restored, the MCS will disconnect the 100 kW solar array and synchronize output from spinning generators 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 both minimum or maximum export limits and 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 100 kW solar array back on-line.

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

2.8 Information Technology and Telecommunications Infrastructure (Sub Task 2.6)

The existing information technology and telecommunication infrastructure in Moreau is best suited for a wireless microgrid communication system. The network will rely on several existing network switches distributed throughout the Town. The microgrid design requires 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

Moreau 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 National Grid's WAN thereby controlling data flow and access permissions over the integrated MCS and overarching IT architecture.[10] 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 National Grid'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 National Grid 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 device disconnects, the program disables the port and thus prevents an unauthorized device that may have malicious code from entering the IT system.

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 Moreau 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

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

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 used 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 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 completed a preliminary design for a reliable microgrid. Control components will efficiently manage the real-time operation of the microgrid by communicating with distributed intelligent electronic devices. The proposed design is resilient to forces of nature and cyber threats, and offers full automation and scalability at every level. Its vendor agnostic SOA-based framework promotes interoperability between standard off-the-shelf components, ensuring continuous and smooth operation of the microgrid.

In conclusion, the project is technically feasible. The project requires minimal expansion of electrical distribution lines—new generators will need lines that connect to existing feeders, but the design utilizes existing feeders to connect facilities. The design includes automated isolation switches to disconnect the microgrid from the local feeder and downstream loads as well as switches that will disconnect non-microgrid loads between switches 1, 5, and 8 (see Figure 3). The new solar array will bring the microgrid's renewable energy generation capacity to 130 kW and will operate continuously throughout the year. In island mode, 500 kW of low-emission natural gas-fired spinning generation will provide sufficient electricity to connected facilities. Existing natural gas infrastructure in the Town will support continuous operation of the proposed natural gas reciprocating generator and existing natural gas backup generators.

The main barrier to completion will be obtaining funding for the project's capital costs. The utility (National Grid) must also agree to the new interconnection and electrical distribution network (because it will incorporate National Grid lines and switches), and two facilities (Town Clerk's Office and Fire Company) need to agree to host the proposed reciprocating generator and solar arrays. These facilities must also support interconnection of their existing backup generators and solar array. Existing and proposed generation assets and microgrid components must be available for maintenance at all times. The team is still 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—these facilities have considerable incentive to support the project, as construction and interconnection will guarantee a reliable power supply and possibly provide DER asset owners with new sources of revenue.

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 National Grid may own the control and distribution infrastructure. National Grid has indicated to the Project Team an initial interest in owning and operating the distribution assets related to the microgrid.
- The natural gas-fired reciprocating generator and new 100 kW solar array will sell electricity to National Grid at the average local supply charge (the price National Grid currently pays to purchase electricity, excluding transmission, distribution, and capacity charges).
- National Grid, as the local expert in energy distribution and the current owner and operator of the Town's distribution infrastructure, may operate the microgrid. National

Grid's existing infrastructure is used extensively in the preliminary microgrid design, so operational participation from the utility is vital to the project's success.

- The current regulatory, legal, and policy environment will stay consistent. The proposal falls within the existing frameworks.

The microgrid design relies on the SPV to finance the construction of the 300 kW natural gas reciprocating generator and the 100 kW solar PV array, while National Grid will operate the required microgrid infrastructure and control components. The Moreau microgrid proposal will not qualify for ancillary services or DR given the small size and placement on the feeder with downstream loads. The project is therefore entirely reliant on power sales to National Grid, which will be insufficient to cover operating expenses and will not recover capital expenditures. Simply selling electricity at National Grid's average supply price is not likely to generate sufficient cash flow to attract investor interest in the project in the absence of NY Prize.

3.1 Commercial Viability – Customers (Sub Task 3.1)

The preliminary microgrid design includes eight facilities and a group of residential units (see Figure ES-1 for a list of included facilities). Private investors, through the SPV, will own the proposed DERs and National Grid will own and operate the microgrid components and control infrastructure. National Grid's expertise will be helpful in the day-to-day operation of the microgrid. The proposed DERs will operate continuously throughout the year, selling electricity to National Grid under a long-term power purchase agreement in grid-connected mode (the normal mode of operation) and directly to microgrid customers in island mode. DER owners will remit payment to National Grid to support the costs of the control infrastructure.

Four of the connected facilities provide critical services to the Town during emergency situations. The Town of Moreau and South Glens Falls Fire Company[11] own backup natural gas generators that will be connected to the microgrid. Owners of existing generation assets will maintain ownership and may sell electricity to connected facilities in island mode. The project will affect several groups of stakeholders in the Moreau 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 Moreau microgrid will serve four critical facilities, four important facilities, and a group of residential units that fall within the footprint of the microgrid (see Table 12 for a list of direct microgrid customers). These customers will continue to purchase electricity from National Grid most of the year. However, during an outage on the National Grid system, the microgrid will switch to island mode, and customers will purchase electricity directly from the microgrid DERs. The transition to islanded operation may be intentional or unintentional.

[11] Moreau is also referred to as South Glens Falls and is not to be confused with the NY Prize microgrid project in Glens Falls proper. The fire department is within the Town of Moreau's footprint as seen on the map in Figure ES-1.

Although facilities outside the microgrid's footprint will not receive electricity from the microgrid's generation assets during emergency outages, they will benefit from the availability of critical and important services. In their day-to-day operations, each of the microgrid facilities serves the larger community. By providing critical services to the community, these facilities extend their reach beyond direct employees and residents in the event of emergencies. Section 4.6 provides estimated customer counts for each critical facility during outage and non-outage situations.

Table 12 below identifies each of the direct microgrid customers and the scenarios during which they will purchase services from the microgrid. The full group of stakeholders that will benefit from the microgrid is discussed in Section 3.2.6.

Table 12. Microgrid Customers

Table provides a list of facilities that will be connected to the microgrid. All facilities will purchase electricity from the microgrid in island mode.

Property	Address	Classification	Critical Service	Backup Generation
Town of Moreau Town Clerk's Office	351 Reynolds Rd	Public	Yes	Yes (Natural Gas)
South Glens Falls Fire Company	Reynolds Road	Public	Yes	Yes (Natural Gas)
Moreau Family Health	1448 US Route 9	Health	Yes	No
Wallace Supply Co Inc.	1434 US Route 9	Private	No	No
Landmark Motor Inn	1418 US Route 9	Private	No	No
Hess Express Gas Station	411 Reynolds Rd	Private	No	No
Saratoga County Sheriff's Office	353 Reynolds Road	Public	Yes	No
ANNEX Storage building	349 Reynolds Road	Private	No	No
Residential Load Group	Reynolds Road	Residential	No	No

3.1.2 Benefits and Costs to Other Stakeholders

Stakeholders in the Moreau microgrid extend beyond connected facilities to include SPV investors, owners of existing generation assets, National Grid, and residents of Moreau and the surrounding communities.

Most benefits and costs to microgrid stakeholders fall into the following categories:

- Resilient power supply during emergency outages
- Electricity generation in grid-connected mode
- Cash flows to DER owners
- Upfront capital investment and land requirements

Resilient power supply during emergency outages: The microgrid will supply power to four critical facilities that will provide shelter, law enforcement, emergency services, and healthcare to the Town and surrounding communities during long-term grid outages. The natural gas unit will be containerized, and the solar PV will be as resilient to weather as the technology and construction allows, however there is no way to physically encase the asset.

Electricity generation in grid-connected mode: The new 300 kW natural gas reciprocating generator and 100 kW solar array will operate continuously in grid-connected mode, pushing electricity to National Grid under a custom long-term PPA. Continuous energy generation will reduce load for the larger National Grid 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 Moreau is not considered a critical congestion point on the larger National Grid and NYISO systems, peak load support from proposed generation assets will reduce congestion costs to NYISO, National Grid, and their electricity customers.

Cash flows to DER owners: Cash flows will be limited to energy sales to National Grid. The microgrid project will produce negative operating cash flows and will not be sufficient to cover financing costs or recover initial capital costs. The project's commercial viability therefore depends on NYSERDA NY Prize Phase III funding and additional subsidization.

Upfront capital investment and land requirements: The primary costs will be purchasing and installing necessary microgrid equipment and proposed generation assets. The Town of Moreau has extensive land available for the proposed ground-mounted 100 kW solar PV array, but the array will prevent the land from being used for other purposes.

3.1.3 Purchasing Relationship

In grid-connected mode, the SPV will sell electricity from the proposed reciprocating generator and 100 kW solar array to National Grid under a long-term PPA.[12] Microgrid connected facilities will maintain their current electricity-purchaser relationship with National Grid during grid-connected mode. In island mode, however, the facilities will be physically disconnected from the larger grid and directly supplied by the proposed generation assets. Associated usage will be captured by the microgrid software and revenues remitted to the SPV as appropriate.

Islanded operation contracts will be established during development and construction and will address 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 and 6 below for the purchasing relationships.

[12] 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. The 100 kW solar array may also exceed the maximum capacity for net metering. The Town Clerk's Office average electricity demand in 2014 was ~25 kW.

Figure 5. Normal Operation Purchasing Relationship

Figure describes the value streams and purchasing relationships between the various entities during normal operation.

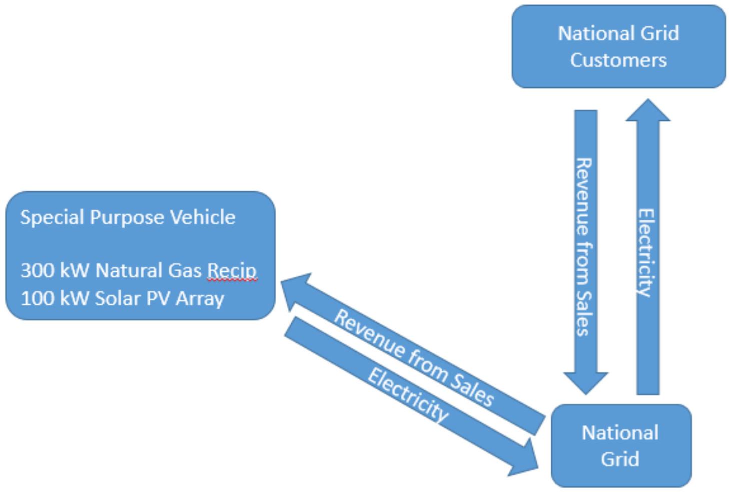
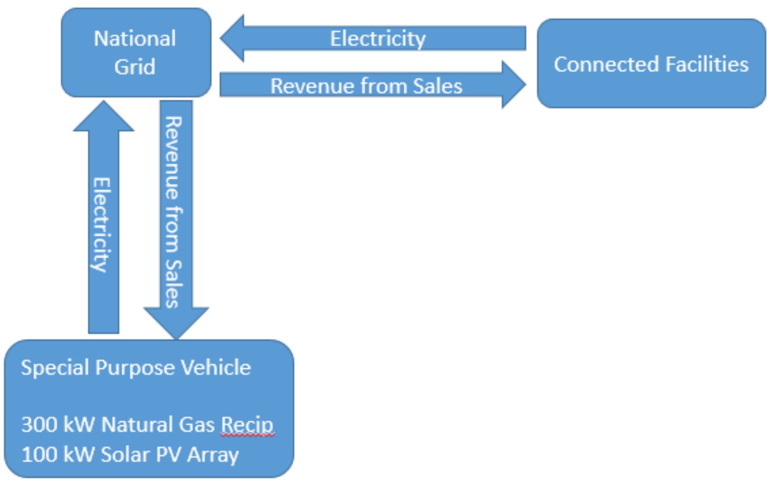


Figure 6. Islanded Operation Purchasing Relationship

Figure describes the value streams and purchasing relationships between the various entities during islanded operation.



3.1.4 Solicitation and Registration

The microgrid design team will work with the Town and utility to formalize agreements with the critical facilities identified. This outreach will include informal discussions and, ultimately, signed agreements of participation in the microgrid and fee structure determined by the NY Public Service Commission. Formal registration with the microgrid will be managed by 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 300 kW natural gas-fired reciprocating generator and a 100 kW solar PV array. During normal operation, this energy will be sold to National Grid and distributed on the National Grid system as dictated by their loads and electricity needs. If, conversely, National Grid 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 volume of electricity purchased from the natural gas reciprocating generator will depend on the generator's output as dictated by the microgrid controllers, system demand, and agreements between the SPV and National Grid. The reciprocating generator will not participate in NYISO ancillary service markets because most lucrative markets require at least 1 MW of available capacity. Ancillary service markets that do not have minimum capacity requirements (such as spinning and non-spinning reserves) rarely offer competitive payments. As such, ancillary services sales are unlikely. None of the current microgrid facilities have sufficient thermal energy demand to merit the addition of combined heat and power capability.

The microgrid will not enter islanded operation for economic reasons as downstream loads on the feeder would be adversely affected.

3.2 Commercial Viability – Value Proposition (Sub Task 3.2)

The microgrid will provide value to the Town of Moreau, private investors, National Grid, direct participants, and the larger State of New York. The new 100 kW solar array and 300 kW natural gas generator will produce reliable, relatively low-emission electricity in both normal and islanded operation. Backup natural gas generators will come on-line as necessary in island mode. SPV members will receive stable, though negative, 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.

Table 13 below provides an overview of the Moreau microgrid project, including an analysis of project strengths, weaknesses, opportunities, and threats (SWOT).

Table 13. Moreau Microgrid SWOT

Table includes a discussion of the strengths, weaknesses, opportunities, and threats (SWOT) associated with the Moreau microgrid project.

Strengths	Weaknesses
• Full National Grid participation in operation and infrastructure and controls ownership may demonstrate to other IOUs the value of community microgrids in their service territories and prove out a win-win for the utility and ratepayers • Allows for the use of existing transmission and distribution (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) • Draws on National Grid's expertise to facilitate daily operation of the microgrid (load aggregation, load following, voltage regulation, and other requirements) • Engages key critical facilities as well as local residents and businesses	• Selling electricity at National Grid's supply price will not recover all initial investment costs nor will it cover operational expenses due to the relatively small generation assets and commensurate power sales. NY Prize Phase III is a requirement to project viability. • Separating significant capital costs from the revenues necessitates further agreement between revenue drivers (DERs) and control infrastructure owners. DER owners may balk at paying revenue into non-revenue generating components
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 silent DERs investor group • Provides data for National Grid and NYSERDA on the benefits of using non-CHP natural gas reciprocating generators as DER assets. The market for non-CHP recip. generators is far larger than the market for CHP because it is not limited by thermal demand	• 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 National Grid's purchasing price

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** – SPV members will seek a long-term PPA, or some other form of long-term purchase agreement, with National Grid 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. National Grid's average supply price of electricity is also too low for the microgrid's owners to fully recover initial investment costs without subsidies. Moreover, operating expenses are projected to exceed revenues, yielding negative operating cash flow and providing no opportunity to recover costs. This weakness is partially offset by NY Prize Phase III funding, which is a requirement for project viability.

- **Organizational Competition** – This business model requires collaboration among groups of stakeholders that may have different motivations for participation in the microgrid project. National Grid may construct and own non-revenue generating control and switchgear with an expectation of financial support from DER revenues. DER owners will see significant revenues from their assets and may be disinclined to support the non-revenue assets. Further, though National Grid will have no ownership interest in the generation assets, they may have day-to-day operational responsibility for them according to an agreement with the SPV. This arrangement may misalign incentives if National Grid can source electricity from other suppliers at a lower rate than the price paid to the SPV. Given that the SPV will cede operational control to National Grid and will exist in a silent investment capacity, the SPV will have little immediate recourse in addressing lower than expected revenues. Open communication and early agreement between National Grid and private DER investors regarding operational parameters, volumes of electricity to be purchased, and the price per unit of electricity will be paramount for the smooth operation of the microgrid.
- **Regulatory** – Utilities in New York State cannot own generation assets unless they demonstrate why full vertical integration provides value to their customers. The State of New York wishes to avoid situations in which a single entity monopolizes energy generation and distribution resources. Utilities may not purchase DERs, and microgrid investors that purchase distribution infrastructure may be considered utilities. To avoid this regulatory threat, the SPV will purchase only new generation assets, while National Grid will retain ownership of existing power lines and new distribution infrastructure. The proposed business model will therefore function within the existing regulatory landscape and may provide evidence that privately owned generation assets can successfully sell electricity over a utility-owned power distribution platform.

3.2.1 Replicability and Scalability

The Moreau microgrid is a largely replicable and scalable model and 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, Supervisory Control and Data Acquisition (SCADA), and Energy Management System, are widely available and could be repeated in any location. All interconnections with the National 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 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 that contracts the local utility to operate the DERs, 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. A model in which an IOU has full operational control over the generation assets but without any financial stake in them is not one that has been widely implemented. It is the opinion of the Project Team, however, that 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 model may also promote innovations in rate calculations and help change the services that IOUs are expected to provide. Its replicability expands the potential market for resulting innovations to include a larger part of New York State. As such, this project presents a valuable opportunity for NYSERDA to examine the changing role of the investor owned utility in energy generation and distribution.

The proposed generation assets qualify for a relatively small total incentive payment—the NY Sun program may offset around 30% of the solar array's capital cost, but the natural gas reciprocating generator is not covered by any state or federal incentive programs. The project's commercial viability therefore depends on NYSERDA NY Prize Phase III funding, which will not be available to most community microgrid projects and is not itself sufficient to lift the project to profitability. This hinders the project's replicability.

Scalability. The Moreau microgrid is scalable on the Butler Sub 362 feeder; however, expansion would require the addition of new isolation switches as well as additional generation. Expanding the microgrid to adjacent feeders would require new lines, new switches and breakers, and additional power flow studies to ensure safe operation of the microgrid. It also assumes congruent line voltage, without which the linkage of different feeders would become more electrically complex.

3.2.2 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 many years to come, 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 14 through 19. Moreover, except for a marginally increased price of electricity during island mode to compensate for the operation of the existing backup generators, the customers and local community will not bear any of the project's costs. However, the cash flows generated by proposed DERs will not fully recover initial investments at National Grid's average supply rates and NY Prize Phase III will not alone bridge this gap. 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 14 through 19 below provide an overview of the benefits and costs to members of the SPV, direct microgrid customers, citizens of Moreau and surrounding municipalities, and the State of New York.

Table 14. Benefits, Costs, and Value Proposition to SPV

Table describes the benefits, costs, and value proposition to SPV shareholders.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
SPV (Private Investors)	- Investors will receive annual cash flows from electricity sales from the natural gas reciprocating generator and PV array - NY Sun incentive may recover 30% of solar array's cost in the project's first year - NY Prize Phase III funding would recover 50% of capital costs	- Initial capital outlay will be moderate because the SPV must purchase and install generation assets - Forecasted installed capital costs for the solar array and natural gas reciprocating engine are $240,000 and $390,000, respectively - Ongoing operation and maintenance of DERs - Financing costs associated with initial capital outlay will persist for many years	- Low risk returns ensured through long-term purchase contracts make the DERs a steady revenue source, however revenues will not cover operating expenses

Table 15. Benefits, Costs, and Value Proposition to National Grid

Table describes the benefits, costs, and value proposition to National Grid.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
National Grid	- The utility will continue to sell electricity to direct customers - National Grid will maintain full control of distribution lines and new control infrastructure, as well as operational control of the DERs - 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	- National Grid will purchase electricity from the natural gas reciprocating generator at a price consistent with its existing electricity supply costs - National Grid may bear the cost of installing and maintaining the microgrid control infrastructure	- The utility can serve as a market connector, realizing revenue from transmission and distribution and fees from the DERs - Improved grid resiliency by integrating local generation assets with local distribution networks - National Grid will have a new supply of electricity valued at their average T&D supply charge but may marginally reduce their costs in the immediate area

Table 16. Benefits, Costs, and Value Proposition to the Town of Moreau

Table describes the benefits, costs, and value proposition to the Town of Moreau.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Town of Moreau	- The Town Clerk's Office will receive backup power from proposed DER assets—this will reduce the need for future investments in backup generation capabilities - The microgrid will provide a resilient and redundant energy supply to critical services - Reduced emissions during peak demand events	- When the microgrid enters island mode due to a larger grid outage, customers will 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 Moreau 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 a natural gas-fired reciprocating generator will offset potential diesel backup generation

Table 17. Benefits, Costs, and Value Proposition to Connected Facilities

Table describes the benefits, costs, and value proposition to connected facilities.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Connected Facilities	- Resilient and redundant energy to supply operations - Access to a local market for distributed energy generation makes investments in small DERs more attractive to connected facilities	- Potential for slightly higher electricity prices during island mode	- Maintain operations during emergency outages and provide valuable critical services to the Moreau 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

Table 18. Benefits, Costs, and Value Proposition to the Larger Community

Table describes the benefits, costs, and value proposition to the larger community.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Community at Large	- Access to a 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 significant costs	- Potential for reconnect in outage situations if generation assets are out-producing the demanded 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 Moreau will likely need to install AMI meters this to be feasible

Table 19. Benefits, Costs, and Value Proposition to New York State

Table describes the benefits, costs, and value proposition to New York State.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
New York State	- DER assets 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	- 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

3.2.3 Demonstration of State Policy

The proposed microgrid represents a 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. The ownership model has the potential to be extremely successful by leveraging private capital as well as local utility expertise, and it is replicable. The proposed organizational construct provides an approach that has not yet been implemented on a large scale in NY State with private finance having full ownership of the generation assets while the local utility retained full operational control. While there are potential challenges in such an arrangement, the Project Team believes that this somewhat novel approach to the microgrid incentivizes both investors and the utility sufficiently to gain buy-in, and when the utility desires to be engaged in the ownership and operation of the microgrid from the outset, it creates strong momentum for success. Table 13, above in Section 3.2.2, outlines the strengths and weaknesses of this proposed model and the opportunities that it may present. This project could therefore serve as a valuable example of innovative, profitable cooperation between IOUs, municipalities, and private investors.

By coordinating the microgrid as a local distributed system platform (DSP), the Moreau 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.

3.3 Commercial Viability – Project Team (Sub Task 3.3)

The Project Team includes National Grid, the Town of Moreau 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 or thermal demand and discuss other aspects of the project development.

3.3.2 Project Team

The Moreau microgrid project is a collaboration between the public sector, led by the Town of Moreau, and the private sector, led by National Grid and Booz Allen Hamilton with significant support from Power Analytics and Siemens. Each of the private sector partners is exceptionally well qualified in the energy and project management space, and the Town of Moreau has strong interest in improving its energy reliability and expanding its clean energy generation capacity. Tables 20 and 21 provide details on the Project Team.

Table 20. Project Team

Table provides background on Booz Allen Hamilton, Siemens AG, Power Analytics, and National Grid.

<table>
<tr><th>Booz Allen Hamilton</th><th>Headquarters: McLean, VA</th><th>Annual Revenue: $5.5 B</th><th>Employees: 22,700</th></tr>
<tr><td colspan="4">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.</td></tr>
<tr><th>Siemens AG</th><th>Headquarters: Munich, Germany;
U.S. Headquarters: Washington, DC</th><th>Annual Revenue: €71.9 B</th><th>Employees: 343,000</th></tr>
<tr><td colspan="4">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.</td></tr>
<tr><th>Power Analytics</th><th>Headquarters: San Diego, CA</th><th>Annual Revenue: $10-15M</th><th>Employees: 50</th></tr>
<tr><td colspan="4">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.</td></tr>
<tr><th>National Grid</th><th>Headquarters: London, UK</th><th>Annual Revenue: £22 B</th><th>Employees: 23,909</th></tr>
<tr><td colspan="4">History and Product Portfolio: Founded in 1990, National Grid is an international electrical and gas company operating in the UK and northeastern US. National Grid provides electric service to approximately 3.4 million customers and gas service to approximately 3.6 million customers across the northeastern US. National Grid receives yearly operating revenues of approximately £15.2 billion.</td></tr>
</table>

Table 21. 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
National Grid	National Grid will work with the Project Team to develop the concept and provide input. They will further provide the financial support for the purchase of microgrid control systems and infrastructure.	National Grid may provide a share of the initial capital outlay that corresponds to the microgrid control infrastructure.	National Grid may provide the necessary domain expertise to operate and maintain the microgrid and DERs. This includes 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 Moreau	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.
Suppliers	There are no suppliers required during this development phase; however, project partners and suppliers Siemens and Power Analytics are closely involved in	Siemens or another engineering and technology firm will be the hardware supplier, including switches and other	The installer of the hardware and software will continue to provide maintenance and advisory services as required to ensure proper

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
	feasibility and design portions of the project. BAH is in touch with several additional suppliers of hardware and software including Duke Energy, Con Ed Solutions, Enel Green Power, Anbaric Transmission, Bloom, and Energize.	physical controls. Power Analytics or another software company will be the EMS and SCADA provider, responsible for software and server components.	and efficient functioning of their components. The software provider will work in cooperation with National Grid 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 resources. National Grid 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, National Grid, 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 National Grid and private investors, through the SPV.

Moody's Investor Service rates National Grid 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." National Grid is an international electrical and gas company operating in the UK and northeastern US. National Grid provides electric service to approximately 3.4 million customers and gas service to approximately 3.6 million customers across the northeastern US. National Grid receives yearly operating revenues of approximately $22.3 billion.

Given the relatively reliable return on investment for solar PV arrays and efficient natural gas-fired generators, the microgrid project should attract attention from outside investors, however the costs of the requisite control system and distributed equipment may be a financial anchor on the project. Negotiating a deal with National Grid that provides for stable sales of electricity will further increase the project's investment appeal.

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. The chosen technologies meet all of the required and most of the preferred capabilities outlined above.

Implementation of a vendor agnostic Service Oriented Architecture framework will enable the microgrid to switch between grid-connected mode and island mode in real time, and it will allow future integration of Building Energy Management Systems using known open standards. The SOA framework will support a SCADA based control center as well as a primary and secondary EMS. The SCADA based control center allows remote monitoring & control of microgrid controllers from a single location; the EMS will be capable of detecting breaks in power lines, isolating problematic sections, and re-routing power. Working with automated switches distributed throughout the microgrid, the EMS will also be programmed with a black-start sequence for sudden and unexpected disconnections of power from the larger grid. These technologies enhance power supply reliability in Moreau by automating the transition to island mode based on real time, accurate data collected in the SCADA control center.

A solar PV array and a natural gas-fired reciprocating generator were chosen as generator technologies to minimize GHG emissions and enhance the reliability of the power supply. The natural gas unit will be capable of automatic load following (responding to load fluctuations within cycles, allowing the microgrid to maintain system voltage and frequency), black starts, and adjusting generation output. The unit will also reduce the need for diesel generation in emergency outage situations. The Project Team performed analyses on the viability of CHP/cogeneration in Moreau, but none of the connected facilities have sufficient thermal energy demand to merit the addition of combined heat and power capability to the proposed reciprocating generator.

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 Moreau and the state closer to the renewable generation goals set forth in state goals and the Renewable Portfolio Standards. PV generation will face the same problems in Moreau that it does elsewhere in the northeastern United States: variable weather conditions and long periods of darkness in the winter.

The Moreau microgrid includes numerous components that have been previously used and validated. Solar PV and reciprocating natural gas generators are both widely used technologies, with more than 6 gigawatts of solar PV installed in 2015 in the United States. 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.[13] 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.[14]

3.4.2 Operation

SPV investors will contribute funds to National Grid's operation and maintenance of the DERs. As the project's subject matter expert and owner of the distribution infrastructure, National Grid 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. The microgrid is a classic shared value entity; the utility, Town, and investors will benefit financially, and the continued success of the grid requires support and collaboration from all three.

National Grid 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, 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 National Grid power grid will be automatically governed by the microgrid controllers.

This analysis assumes National Grid will purchase electricity from the SPV and distribute it across its grid. The facilities will continue to be billed for electricity via the regular National Grid billing mechanism and cycle. National Grid's revenue should be sufficient to cover the supply cost of electricity (from the DERs) as well as National Grid-imposed delivery and capacity charges. Additional fees may be imposed upon microgrid participants as a percentage of their electricity cost. However, given the limited amount of time forecasted in island operation and the commensurately limited time the customers will need to rely on the microgrid, the fee is expected to be extremely marginal or foregone.

3.4.3 Barriers to Completion

The barriers to constructing and operating the microgrid are primarily financial. The high capital costs and relatively long payback make the investment a difficult one, and the absence of local demand for thermal energy confines revenues to electricity sales. Even assuming the SPV will sell electricity to National Grid at their current supply charge through a long-term purchase agreement, the microgrid will produce negative operating cash flows from year to year and will have no ability to cover operating costs or pay down the capital costs of construction. The Moreau microgrid qualifies for relatively few of the available state and federal incentives for

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[13] Siemens case studies; available from http://w3.usa.siemens.com/smartgrid/us/en/microgrid/pages/microgrids.aspx.
[14] http://www.poweranalytics.com/company/pdf/M-12-GE-PPT-X-001-03%202012%20UCSD%20Virtual%20summit.pdf.

DER assets—the NY Sun program may offset 30% of the capital cost of the solar array, but this only amounts to around 4% of total project cost. As such, it must rely on direct project-generated revenues, NY Prize Phase III, and other sources of funding for its commercial viability.

3.4.4 Permitting

The Moreau microgrid may require certain permits and permissions depending on the ultimate design choices. The SPV will need to apply for a special use permit through the Town of Moreau's Zoning Board of Appeals. Moreau is not within any EPA Criteria Pollutant Non-Attainment Zones. The reciprocating generator will further 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 National Grid. 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, which may 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 22. The revenues will sum to approximately $170,000 per year, while fuel, operation, and maintenance will cost around $177,000 per year. Yearly cash flows will be negative and they will be unable to recover initial investment costs (see outline of the capital and operating costs in Table 23). Phase III is therefore necessary but not sufficient to ensure the commercial viability of this project.

Table 22. Savings and Revenues

Table describes 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 300 kW natural gas-fired reciprocating generator during grid-connected mode[15]	Revenue	~$160,000/yr	Variable
Electricity sales from 100 kW solar PV during grid-connected mode	Savings	~$10,000/yr	Variable
Total Yearly Revenue and Savings		**~$170,000/yr**	Variable

[15] The Booz Allen Team calculated National Grid's supply charge for electricity to be approximately $0.0725/kWh in Zone F. This is the assumed price for grid-connected sales from the NG recip. generator generating 85% of possible hours in a year.

Table 23. Capital and Operating Costs

Table describes the expected costs from construction and operation of the microgrid.

Description of Costs[16]	CapEx or Ops	Relative Magnitude	Fixed or Variable
300 kW NG Recip. Generator	Capital	$390,000	Fixed
100 kW Solar PV array	Capital	$240,000	Fixed
Distributed Equipment	Capital	$105,000	Fixed
Microgrid Control System	Capital	$350,000	Fixed
IT costs (wireless and cables)	Capital	$70,000	Fixed
Power lines (overhead)	Capital	$30,000	Fixed
Total CapEx		**$1.2 MM**	Fixed
Design considerations and simulation analysis	Planning and Design	$250,000	Fixed
Project valuation and investment planning	Planning and Design	$50,000	Fixed
Assessment of regulatory, legal, and financial viability	Planning and Design	$25,000	Fixed
Development of contractual relationships	Planning and Design	$25,000	Fixed
Total Planning and Design		**$350,000**	Fixed
NG Generator Fuel[17]	Operating	$75,000/yr	Variable
NG Generator Maintenance	Operating	$30,000/yr	Variable
Solar PV Maintenance	Operating	$2,000/yr	Variable
Microgrid Controls O&M	Operating	$70,000/yr	Fixed
Total OpEx		**$177,000/yr**	Variable

The proposed microgrid may qualify for two existing incentive programs: the Federal solar ITC and NY Sun, which would each cover 30% of the solar array's capital cost. Other possible sources of incentive payments include NYSERDA Phase III NY Prize funding (up to $5 million but will not exceed 50% of total project costs). The microgrid will not enter island mode for economic purposes because doing so would disconnect downstream customers on the Butler Sub 362 feeder. This removes the realization of any demand response or ancillary service revenues. See Table 24 for details on the available incentive programs.

[16] All capital costs and maintenance costs are from Siemens and based on industry standard amounts. See Task 4 for component specific costs.
[17] Fuel costs calculated at $3.71/MCF ($34.30 per MWh generated), 85% capacity.

Table 24. Available Incentive Programs

Table includes all 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	Up to $5,000,000	Required
NYSERDA NY Prize Phase II	Up to $1,000,00	Required
NY Sun	~$70,000	Preferred
Federal Solar ITC	~$70,000	Preferred

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. Awards from Phase II of the NY Prize Community Microgrid Competition would supply most of the funding for project design and development, with the SPV providing capital for any costs that exceed available NYSERDA funding. We anticipate NYSERDA to supply 75% of the required funds for Phase II with the balance coming from a cost-share. This is based on our understanding of the Phase II cost structure as described in NYSERDA RFP-3044. Moreau 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 and National Grid will leverage Phase III funding from NYSERDA to complete the construction phase. Phase III NY Prize funding, which will provide up to $5 million to the SPV for microgrid and DER equipment and installation, will cover half of the capital cost of the project (estimated to be approximately $1.4 million in total), and private and utility funding will represent the balance of the financing. However, the Project is unlikely to generate interest in the investor community with negative operating cash flows.

The Team assumes Moreau will grant the physical space to site the DERs at no cost or as its contribution to the required cost share because it is the primary beneficiary of the proposed microgrid. The SPV will maintain ownership over all generation assets and National Grid over the control infrastructure.

3.6 Legal Viability (Sub Task 3.6)

Like any infrastructure project that involves development of public and private land, the Moreau 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 the 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 National Grid's close participation in the project, the Project Team does not envision any onerous requirements.

Local Regulation

The SPV may need to apply for a special use permit through the Town of Moreau's Zoning Board of Appeals. To apply, the Project Team must submit a description of the project and explanation of why it is in the public interest. The Board may request additional information, such as descriptions of the proposed project location and construction materials.[18] Fire, building, and electric codes require compliance with New York State Uniform Fire Prevention and Building Code, State Energy Conservation Construction Code, and National Electric Code. The project must also abide by the Town of Moreau's General Construction Standards. The Project Team does not foresee any project barriers arising from compliance with these codes.

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 reciprocating generator in Moreau 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 (NSPS) for Stationary Compression Ignition (CI) Internal Combustion Engines (ICE): 40 CFR part 60 subpart IIII
- NSPS for Stationary Spark Ignition (SI) ICE: 40 CFR part 60 subpart JJJJ

[18] *Zoning: Special Use Permits (Chapter 149, Section 5 Municipal Code).*

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. Further, Moreau and Saratoga County are within an EPA Criteria Pollutant Non-Attainment Zone for 1 hour and 8 hour ozone. The natural gas generator will need to abide by any associated restrictions; however, given the small size of the generator and the very low associated ozone emissions, these should not be onerous.

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 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 natural gas unit.

3.7 Project Commercial and Financial Viability Conclusions

The Moreau microgrid project will include four critical facilities, four important facilities, and one group of residential units in the Town of Moreau and will be owned by an SPV and National Grid. Private investors will finance the SPV for the purchase of the DERs, and National Grid may finance the capital expense of microgrid control infrastructure. National Grid may operate the control infrastructure as well as the DERs, under an agreement with the SPV, and will be responsible for the safe operation and maintenance of all components.

The proposed microgrid's commercial feasibility depends on NY Prize Phase III funding and additional support. Its design includes two new DERs to be located at the Town Clerk's Office and Fire Company: a 300 kW natural gas fired reciprocating generator and a 100 kW solar photovoltaic array, respectively. The SPV will provide the capital required to purchase and install these generators and will receive revenues from electricity sales to National Grid throughout the generators' lifespan. Investors in the SPV will contribute funds to the daily operation and maintenance of the DERs, and National Grid may leverage its local expertise to keep the microgrid components and control infrastructure running smoothly. The Project Team forecasts yearly revenues of approximately $170,000 and yearly operation and maintenance costs of approximately $177,000. The project will produce negative annual operating cash flows and it will require subsidies to fully recover initial investment costs.

These estimates and value propositions are predicated on several assumptions.

- Private investors will own the DERs, and National Grid may own the control and distribution infrastructure. National Grid has indicated to the Project Team a potential preference to own and operate the distribution assets related to the microgrid
- The natural gas-fired reciprocating generator and new 100 kW solar array will sell electricity to National Grid at the average local supply charge (the price National Grid currently pays to purchase electricity, excluding transmission, distribution, and capacity charges).
- National Grid, as the local expert in energy distribution and the current owner and operator of the Town's distribution infrastructure, may operate the microgrid. National Grid's existing infrastructure is used extensively in the preliminary microgrid design, so operational participation from the utility is vital to the project's success.
- The current regulatory, legal, and policy environment will stay consistent. The proposal falls within the existing frameworks.

The microgrid will not enter island mode to participate in DR programs, as doing so would disconnect downstream customers on the Butler Sub 362 feeder.

In addition to revenues from electricity sales, the microgrid will provide indirect financial and non-financial benefits to Moreau citizens, SPV shareholders, National Grid, and the larger Saratoga 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 Moreau.

Permitting and regulatory challenges should be reasonably straightforward. The primary regulatory consideration will be the Clean Air Act permitting of the new reciprocating generator. The SPV will also need to apply for a special use permit through the Town of Moreau's Zoning Board of Appeals.

4. Cost Benefit Analysis

Section 4 Cost Benefit Analysis is made up of seven sections in addition to the introduction:

- ***Section 4.1*** analyzes the *facilities connected to the microgrid* and their energy needs.
- ***Section 4.2*** discusses the *attributes of existing and proposed DERs*, including factors such as nameplate capacity and expected annual energy production.
- ***Section 4.3*** analyzes *potential ancillary services sales and the value of deferring transmission capacity investments*.
- ***Section 4.4*** 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 4.5 and 4.6*** 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 4.7*** 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 Moreau microgrid will include eight facilities and one residential load cluster from various rate classes and economic sectors. There are three primary rate classes based on type of facility and annual electricity consumption: residential, small commercial (less than 50 Megawatt-hour (MWh) per year), and large commercial (greater than 50 MWh per year). See Table 25 for basic statistics on each facility's energy usage. Six of the nine microgrid facilities belong to the large commercial rate class requiring approximately 1,498 MWh of electricity per year. The two facilities belong to the small commercial rate class and use approximately 80 MWh per year. The remaining residential load cluster uses approximately 159.8 MWh per year. Additionally the average aggregate demand of all connected facilities in 2014 was 0.198 MW and rose as high as 0.523 MW.

There are four kinds of facilities in the microgrid: commercial, health, public and residential. The commercial facilities include Wallace Supply Co Inc., Landmark Motor Inn, Hess Express Gas Station, ANNEX Storage Building. These facilities total to 57% of the microgrid's total annual electricity usage. The health facility, Moreau Family Health, comprises 4% of the annual electricity usage. The public facilities are the Town Clerk's Office, South Glens Falls Fire Company and Saratoga County Sheriff's Office; they make up the 30% of the facility electricity usage. The residential load cluster makes up 9% of the microgrid 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. In these situations, the backup generators may need to come online to supply additional electricity. For information on each facility's average daily operation during a major power outage, see Table 25.

Table 25. Facility and Customer Detail Benefit[19]

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.

REDACTED PER NDA WITH NATIONAL GRID

[19] Load data was provided to Booz Allen by National Grid.

4.2 Characterization of Distributed Energy Resource (Sub Task 4.2)

The microgrid design incorporates distributed energy resources, including two existing natural gas generators, one existing solar PV array, one proposed natural gas generator, and one proposed solar PV array. The proposed natural gas unit and solar PV arrays (both proposed and existing) will produce an average of 0.273 MW of electricity throughout the year[20] (including projected capacity factors), and the existing backup generators will provide up to 0.2 MW of backup generation capacity during emergencies.

The natural gas generator has a nameplate capacity of 0.3 MW and will operate nearly continuously. Assuming a capacity factor of 85%, the natural gas unit will produce approximately 2,234 MWh of electricity over the course of the year. If a major power outage occurs, the natural gas unit will produce an average of 6.12 MWh of electricity per day, which would provide 100% of the microgrid's average daily demand. The natural gas units use around 9.5 Mcf (1000 ft^3) of natural gas per MWh generated, which amounts to a fuel cost of around $34/MWh to operate.[21]

Limited by weather conditions and natural day-night cycles, the 0.03 MW and 0.1 MW solar PV arrays are expected to produce a combined 159 MWh per year (assuming a capacity factor of 14%). Because many outages are caused by severe weather events, solar arrays cannot be relied upon to provide energy during emergency outages without supplementary battery storage. However, on average the solar arrays will produce a combined 0.44 MWh of electricity per day, which represents 9.2% of average daily electricity demand from microgrid-connected facilities. Maintenance costs for the solar array will be around $2,600 per year,[22] which means the marginal cost of producing solar electricity will be about $34/MWh.[23]

The existing backup generators at the town clerk's office and the South Glens Falls Fire Company will be used only in emergency situations when the microgrid requires a black start or when the proposed natural gas generator and solar arrays are not producing sufficient electricity to meet aggregate demand. Both of these backup generators have a nameplate capacity of 0.1 MW. This combined 0.2 MW of backup generation capacity could be vital in emergency situations, or when the solar array or natural gas unit go offline for maintenance. The Booz Allen team predicts the existing back-up natural gas generator will operate approximately 60% of the time during the 1.96 hours of larger grid outage based on National Grid's Customer Average

[20] 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).
[21] Price of natural gas: $3.71 per Mcf (average National Grid supply price from 2013-2015).
[22] Annual fixed O&M cost: $20/kW per year (NREL, http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html).
[23] Capital cost: $2,400 (Siemens estimate).
Variable cost: 30 years of production at a cost of $20/kW per year (Siemens lifecycle estimate, NREL).
Discount rate: 7% (industry standard discount rate; NREL http://www.nrel.gov/docs/fy13osti/58315.pdf).

Interruption Duration Index from 2013,[24] and therefore predicts that annual output from backup natural gas generators will be insignificant. Based on the CAIDI, the backup natural gas generators will require 3 Mcf throughout the year. 25 In the event of a major power outage, the generators could produce up to 4.8 MWh/day—however, assuming that the CHP and solar will require backup power during only 60% of emergency outage hours, this figure drops to a 1.44 MWh/day.[26] See Table 26 for a detailed list of all proposed and existing distributed energy resources in Moreau.

[24] Grid outage data from DPS 2013 Electric Reliability Performance Report (National Grid average CAIDI).
[25] NG fired internal combustion engine heat rate: 9.573 MMBTU/MWh (2013 EIA average, http://www.eia.gov/electricity/annual/html/epa_08_02.html).
[26] The Booz Allen team forecasts a 60% level of operation from the backup generator based on historical loads and expected generator output. In 2014, the average load in Moreau was 0.198 MW. The natural gas generator and solar arrays can provide an average of 0.273 MW of generation. Load is expected to exceed the proposed generation's maximum output for approximately 60% of time spent in island mode. Solar output is unreliable, but it should provide significant support on the most irradiated days of the year when peak demand is highest.

Table 26. 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). "Normal operating conditions" assumes approximately 1.176 effective hours of operation per year for the natural gas backup generator.

Distributed Energy Resource Name	Location	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 – Existing Solar Panel	Near Town of Moreau Town Clerk's Office	Sunlight	0.03	36.79	0.1	0.24[27]	N/A	N/A
DER2 - Existing Backup Generator	Town of Moreau Town Clerk's Office	Natural Gas	0.1	0.162	2.4	2.4	9.26 Mcf	9.5 MMBTUs
DER3 - Existing Backup Generator	South Glens Falls Fire Company	Natural Gas	0.1	0.162	2.4	2.4	9.26 Mcf	9.5 MMBTUs
DER4 - Proposed Natural Gas Generator	Behind South Glens Falls Fire Company	Natural Gas	0.3	2,233.8	6.12	7.2	9.26 Mcf	9.5 MMBTUs
DER5 - Proposed Solar Panel	Near Town of Moreau Town Clerk's Office	Sunlight	0.1	122.64	0.34	0.8	N/A	N/A

[27] 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. Although continuous operation will limit the natural gas generator's ramp-up capability during peak demand events, it will also maximize revenue for owner of the mircrogrid. See Table 27 for the maximum generation capacities of the proposed and existing DERs.

The proposed solar arrays will be at their most productive on days with peak solar irradiance when peak demand events are common, thus providing peak load support when it is most needed. They will provide around 0.0182 MW 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 27. Distributed Energy Resource Peak Load Support

Table shows the available capacity and impact of the expected provision of peak load support from each DER. Existing generation was not included because it is not expected to generate electricity outside of emergency island mode situations (existing natural gas backup generators).

Distributed Energy Resource Name	Location	Available Capacity (MW)	Does distributed energy resource currently provide peak load support?
DER1 – Existing Solar Panel	Near Town of Moreau Town Clerk's Office	Maximum of 0.03	Yes
DER4 - Proposed Natural Gas Generator	Behind South Glens Falls Fire Company	Maximum of 0.3	No
DER5 - Proposed Solar Panel	Near Town of Moreau Town Clerk's Office	Maximum of 0.1	No

4.3.2 Demand Response

Demand response programs require facilities to curtail load or expand generation using generators or battery storage in response to forecasted or real-time peak demand events on the larger grid. Entering island mode is the primary method for a microgrid to reduce load on the larger grid and thus participate in DR programs. However in the Moreau microgrid entering into island mode also disconnects facilities downstream from the microgrid from the grid. This is a high price to pay for islanding, thus the mircrogrid will only island when there is a grid-wide outage. Therefore the microgrid's ability to participate in DR programs is limited to reducing energy usage or expanding energy generation on the level of individual generators or loads. The Project Team is currently assuming a high baseline level of operation for the natural gas generator and therefore negligible participation in DR programs. Additionally, the solar arrays' variable production prevents reliable participation in DR programs.

4.3.3 Deferral of Transmission/Distribution Requirements

The 0.273 MW of average local generation produced by the DERs will slightly reduce the amount of electricity imported from the larger NYISO and National Grid power lines, which may defer the need to invest in new or upgraded power lines. Although these power lines will last up to one hundred years if well maintained,[28] they can only transmit a limited amount of power. As demand for electricity in Moreau increases, the lines might need to be supplemented to handle additional load.

The same is true for distribution capacity investments on a local, feeder-by-feeder basis. However, constructing DERs could actually increase the distribution capacity investment cost in certain cases (e.g., if the assets are placed in remote locations and thus expensive to connect to the local grid). Although Moreau has ample capacity within the town, approximately 550 feet of new distribution lines will be need to be built to properly connect the microgrid facilities and will require a significant distribution capacity investment.

4.3.4 Ancillary Service

None of the existing and proposed generation resources in Moreau will participate in ancillary services markets. Although the natural gas generator 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 three-quarters of the natural gas generator's maximum output. If the natural gas generator runs at projected levels, it will never have the minimum regulation capacity available.

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

4.3.5 Development of a Combined Heat and Power System

Due to lack of thermal off-takers within a technically feasible distance of the generation site, the Project Team decided to use a natural gas generator instead of a combined head and power unit. Therefore there is no proposed CHP unit for the Moreau microgrid.

4.3.6 Environmental Regulation for Emission

The microgrid's generation assets will drive a net 357 $MTCO_2e$ (metric tons CO_2 equivalent) increase in GHG emissions in Moreau as compared to the New York State energy asset mix. The

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

proposed generation assets will produce around 2,393 MWh of electricity per year. The proposed natural gas unit and backup generators will emit approximately 1,226 $MTCO_2e$ per year, 29 while the solar arrays emit nothing. The current New York State energy asset mix would emit approximately 869 $MTCO_2e$ to produce the same amount of electricity.[30] The microgrid's generation assets will therefore result in a net increase in emissions by 357 $MTCO_2e$.

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 natural gas 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.

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. The existing natural gas generator is already permitted and therefore will not incur any significant emissions costs.

Table 28 catalogs the CO_2, SO_2, NO_x, and Particulate Matter (PM) emissions rates for the natural gas generator.

[29] NG generator Emissions Rate: 0.51 $MTCO_2e$/MWh (assuming 117 lb CO_2e per MMBTU; EIA, http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11).
[30] 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).

Table 28. 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)
DER2 - Existing Backup Generator	Town of Moreau Town Clerk's Office	CO_2	0.553
		SO_2	0.0000067[31]
		NO_x	0.00055[32]
DER3 - Existing Backup Generator	South Glens Falls Fire Company	CO_2	0.553
		SO_2	0.0000067[17]
		NO_x	0.00055
DER4 - Proposed Natural Gas Generator	Behind South Glens Falls Fire Company	CO_2	0.00055
		SO_2	9.09358E-07[33]
		NO_x	0.006309834
		PM	1.19237E-07

4.4 Project Costs (Sub Task 4.4)

4.4.1 Project Capital Cost

The microgrid design requires the following new pieces of equipment at the substation and across the rest of 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 44 kV utility breaker at the substation as well as the smaller 13.2 kV distribution feeders.
- Automated breakers installed throughout Moreau 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 distributed equipment is estimated to be $736,000, $20,000 for the IT infrastructure and $27,000 for overhead powerline installation.[34] The Project Team estimates the 0.1 solar PV arrays and 0.3 MW natural gas unit carry an installed costs of $240,000 and $390,000, respectively.[35] This brings the total installed capital cost to approximately $1.38 million or $1.65 million (depending on powerline installation type), 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

[31] Emissions calculator, EPA.
[32] EPA, http://www3.epa.gov/chp/documents/faq.pdf.
[33] "Natural Gas-fired Reciprocating Engines" – EPA, http://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s02.pdf.
[34] Cost estimate prorated from cost estimates provided by Consolidated Edison.
[35] Natural Gas Generator Capital Cost: $1,300/kW (Siemens Natural Gas estimate).
Solar PV Capital Cost: $2,4000/kw (Siemens Solar PV estimate).

microgrid. See Tables 29 and 30 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 (Siemens SICAM PAS or equivalent), which will be replaced by more advanced software after 7-8 years. Operating and maintenance cost data in Table 32 does not include replacement costs for microgrid components.

Table 29 details capital cost of the distributed equipment; it includes the microgrid control system and centralized generation controls that will allow the operator and electronic controllers to manage the entire microgrid. Hardening measures for the distributed equipment have been embedded into their reported costs.

Table 29. Distributed Equipment Capital Cost

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

Distributed Equipment Capital Costs				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
Microgrid Control System	1 Primary	$50,000	7 - 8	Protocol Converter responsible for operating the microgrid's field devices via protocol IEC-61850.
(Siemens SICAM PAS or equivalent)	1 Back-up			
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)	8	$190,000	20	Upgraded and new breakers/switches at 8 distribution overhead switches. Isolate the feeder and downstream loads from the microgrid
Automated Underground Circuit Breaker/Switch (Siemens 7SJ85 relay or equivalent)	5	$50,000	20	New breakers/switches at 5 distribution underground switches. Isolate the downstream loads from the microgrid
Generation Controls (OEM CAT, Cummins, etc.) (Load Sharing via Basler, etc.)	3	$12,000	20	Serves as the primary resource for coordinating the paralleling load matching and load sharing of spinning generation.
PV Inverter Controller (OEM Fronius or equivalent)	1	$4,000	20	Controls PV output and sends data to MCS for forecasting.

Distributed Equipment Capital Costs				
Capital Component	Quantity	Installed Cost ($) (+/- 30%)	Component Lifespan (Years)	Purpose/Functionality
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	9	$18,000	20	Each subscriber unit can communicate back to the WiMax base station for SCADA monitoring and control or remote relay to relay GOOSE messaging.
WiMax configuration and testing	1	$24,000	-	The configuration and testing of the WiMax hardware
Installation Costs	1	$80,000	-	Installation of capital components in the microgrid

Table 30. 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
0.1 MW PV System	1	$240,000	30	Generation of electricity
0.3 MW Natural Gas Unit	1	$390,000	20	Generation of electricity

The microgrid IT infrastructure will also require Cat-5e Ethernet cables 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. 36 The total installation cost of cabling is approximately $5.65 per foot. 37 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 $20,000. 38

[36] Commercially available RJ-45 connectors, $0.30 per connector.
[37] Installation costs for Cat5e: $5.45/ft. Component cost for Cat5e: $0.14/ft (commercially available).
[38] The Project Team estimated ~3,550 feet of Cat5e.

In addition to the microgrid IT infrastructure, the microgrid will need new distribution lines in order to connect the DERs to the microgrid supported facilities. The Project Team has determined the approximate cost of building these new lines is $27,000 for overhead installation.[39]

4.4.2 Initial Planning and Design Cost

The initial planning and design of the microgrid includes four preparation activities and total to approximately $350,000.

1. The first set of activities are the design considerations and simulation analysis which will cost approximately $250,000 to complete.
2. The second activity focuses on the financial aspects of the project including project valuation and investment planning which will cost approximately $50,000.
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 $25,000.
4. The fourth activity focuses on the development of contractual relationships with key partners will cost approximately $25,000.

A breakout of the initial planning and design costs are illustrated in Table 31 below.

Table 31. 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 ($)[40]	Cost Components
$250,000	Design considerations and simulation analysis
$50,000	Project valuation and investment planning
$25,000	Assessment of regulatory, legal, and financial viability
$25,000	Development of contractual relationships
$350,000	**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.

[39] The Project Team has determined that approximately 550 feet of new line is required at the cost of $60/ft for overheard installation according to Consolidated Edison estimates.
[40] Estimates developed by Booz Allen Project Team and independent consultant.

Annual service for the backup natural gas units and solar array will cost approximately $3,000 and $2,600, respectively.[41] The microgrid owner will also incur $31,000/year in costs for annual fixed system service agreements for the proposed natural gas generator. [42]

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 natural gas generator will require capital for fuel, consumable chemicals, and other operating expenses. The average price of natural gas for the microgrid will be $3.71/Mcf, which translates to an average fuel cost of $34/kWh for the natural gas unit.

The solar PV arrays will not require fuel to operate, and it should not require service outside of the normally scheduled downtime. Normally scheduled downtime should cost approximately $20/kW per year.[43]

Annual service for all non-DER microgrid components will cost approximately $70,000 per year.[44]

Table 32 outlines all fixed operations and maintenance costs associated with normal operation of the DERs.

Table 32. 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?
~ $2,600 (total)	Solar PV System Service Agreements – Annual costs of maintenance and servicing of unit
~ 31,000	Natural Gas Generator Service Agreement – Annual costs of maintenance and servicing of unit
~ 3,000	Backup Natural Gas Generator Service Agreement – Annual costs of maintenance and servicing of unit
$70,000	Non-DER Microgrid Components Service Agreement - Annual costs of maintenance and servicing of components

[41] $1,500 per natural gas backup generator (Pete Torres, Prime Power; yearly service for small scale natural gas generator) and $2600 for solar PV array ($20/kW per year).
[42] Natural Gas O&M: $0.014/kWh. (Siemens estimate).
[43] NREL (projects $0/kWh variable maintenance costs): http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.
[44] O&M for non-DER microgrid components: $70,000/year (Siemens).

4.4.4 Distributed Energy Resource Replenishing Fuel Time

The both natural gas units will have a continuous supply of fuel unless the pipeline is damaged or destroyed, therefore the natural gas units will be able to operate continuously. There is effectively no maximum operating duration for the natural gas units in island mode. DERs such as diesel generators have limited tank sizes and have clear maximum operating times in island mode.

The solar PV arrays do not require fuel for operation, but its output depends on weather and time of day.

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 proposed natural gas generator will be the most reliable and productive of the DERs, providing an average of 0.255 MW to the microgrid at any given time. Because the natural gas generator will use natural gas via pipeline as fuel, disruptions to its fuel source are unlikely. The natural gas generator can generate on average 6.12 MWh per day, using approximately 66.6 Mcf (68.4 MMBTU) of natural gas. The natural gas generator 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 at their most productive. On average the solar PV array will provide 0.0182 MW of load support to the Moreau microgrid. Table 33 shows all of the costs associated with operating the DERs during a power outage, including fuel and variable O&M costs.

The backup natural gas generators will only come online when the natural gas unit and solar arrays do not provide sufficient power to the islanded microgrid. Because the backup natural gas generators can produce a combined 0.2 MW of power at full capacity and the microgrid's loads had an average power demand of 0.198 MW during 2014, the natural gas generator and solar arrays should be capable of satisfying the microgrid's power demand in all situations with the assistance of the backup generators. The backup generators will be necessary 60% of total outage time. At full capacity the combined 0.2 MW of generation would produce a total of 4.8 MWh per day during a widespread outage; the backup generators will require around 44.4 Mcfs per day. One-time startup costs or daily non-fuel maintenance costs for either of the natural gas backup generators are not anticipated.

Table 33. 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.

Location	Distributed Energy Resource	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		
Near Town of Moreau Town Clerk's Office	DER1 – Existing Solar Panel	Sunlight	0.03	14%	0.1[45]	N/A	N/A	N/A	$1.65
Town of Moreau Town Clerk's Office	DER2 - Existing Backup Generator	Natural Gas	0.1	100%	2.4	22.2	Mcf	N/A	$86[46]
South Glens Falls Fire Company	DER3 - Existing Backup Generator	Natural Gas	0.1	100%	2.4	22.2	Mcf	N/A	$86[38]
Behind South Glens Falls Fire Company	DER4 - Proposed Natural Gas Generator	Natural Gas	0.3	100%	7.2	66.6	Mcf	N/A	$333[38]
Near Town of Moreau Town Clerk's Office	DER5 - Proposed Solar Panel	Sunlight	0.1	14%	0.34[47]	N/A	N/A	N/A	$5.50

[45] This output assumes that the PV arrays are still operational after an emergency event.
[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 natural gas generator as the key source of emergency power.

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 Table 33. Please refer to Table 33 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 municipally owned buildings that serve the entirety of the population in Moreau (such as the Town Clerk's Office and Saratoga County Sheriff's Office). Others, like Wallace Supply Co Inc., serve a smaller population because they are commercial enterprises. For estimates of the population served by each critical facility, see Table 34.

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 electricity dependency of each service, Table 34 provides an estimate of how effectively each facility can perform its normal services without electricity.

Table 34. 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
Town of Moreau Town Clerk's Office	~ 15,350	0%	> 50%
South Glens Falls Fire Company	~ 15,350	0%	> 50%

[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).

Moreau Family Health	~ 15,350	0%	> 75%
Wallace Supply Co Inc.	~ 15 (employees)	0%	> 75%
Landmark Motor Inn	~ 80[49]	0%	> 75%
Hess Express Gas Station	~ 15,350	0%	> 75%
Saratoga County Sheriff's Office	~ 15,350	0%	> 50%
ANNEX Storage building	~ 15,350	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 Moreau microgrid was delivered to the Project Team on February 18, 2016.

4.7.1 Project Overview

As part of NYSERDA's NY Prize community microgrid competition, the Town or Moreau has proposed development of a microgrid that would serve eight facilities and a residential complex clustered along a 5-mile stretch of Reynolds Road:

- Town of Moreau Town Clerk's Office – a municipal office building
- South Glen Falls Fire Company – a 100% volunteer organization with two stations; Station No.2 is located in the Town of Moreau[50]
- Saratoga County Sheriff's Office (Moreau Substation) – Saratoga County has a total population of approximately 224,000 people; this substation serves the 15,350 residents of the Town of Moreau[51]
- Moreau Family Health – serving community members of all ages and part of the Hudson Headwaters Health Network[52]
- Wallace Supply Company, Inc. – a local hardware store
- Landmark Motor Inn – a local bed and breakfast style hotel
- Hess Express Gas Station – a local gas station
- Moreau Town Annex Building – a municipal storage facility

[49] 77 guest rooms in addition to staff (http://www.hotels.com/hotel/details.html?FPQ=2&WOE=1&q-localised-check-out=12/28/15&WOD=7&q-room-0-children=0&pa=1&tab=description&JHR=1&q-localised-check-in=12/27/15&hotel-id=475948&q-room-0-adults=2&YGF=7&MGT=1&ZSX=0&SYE=3).
[50] http://www.sgffire.org/.
[51] http://www.saratogacountysheriff.org/.
[52] http://www.hhhn.org/HealthCenters/?HCID=5.

The microgrid would incorporate three existing distributed energy resources – two 100 kW natural gas units and a 30 kW photovoltaic array – and two new distributed energy resources – a 300 kW natural gas unit and a 100 kW photovoltaic array. The town anticipates that the natural gas units and photovoltaic systems 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 connected 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 Phase I 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.[53] It also calculates an annualized estimate of costs and benefits based on the anticipated

[53] 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 (NYPSC) 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 PSC notes, "The SCC is distinguishable from other measures

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.[54]

4.7.3 Results

Table 35 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for the scenarios described above. The results indicate that if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to equal or exceed 13.7 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

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.]

[54] 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.

Table 35. BCA Results (Assuming 7 Percent Discount Rate)

Economic Measure	Expected Duration of Major Power Outages	
	Scenario 1: 0 Days/Year	Scenario 2: 13.7 Days/Year
Net Benefits - Present Value	-$3,930,000	$15,100
Benefit-Cost Ratio	0.5	1.0
Internal Rate of Return	n/a	11.1%

Scenario 1

Figure 7 and Table 36 present the detailed results of the Scenario 1 analysis.

Figure 7. Present Value Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

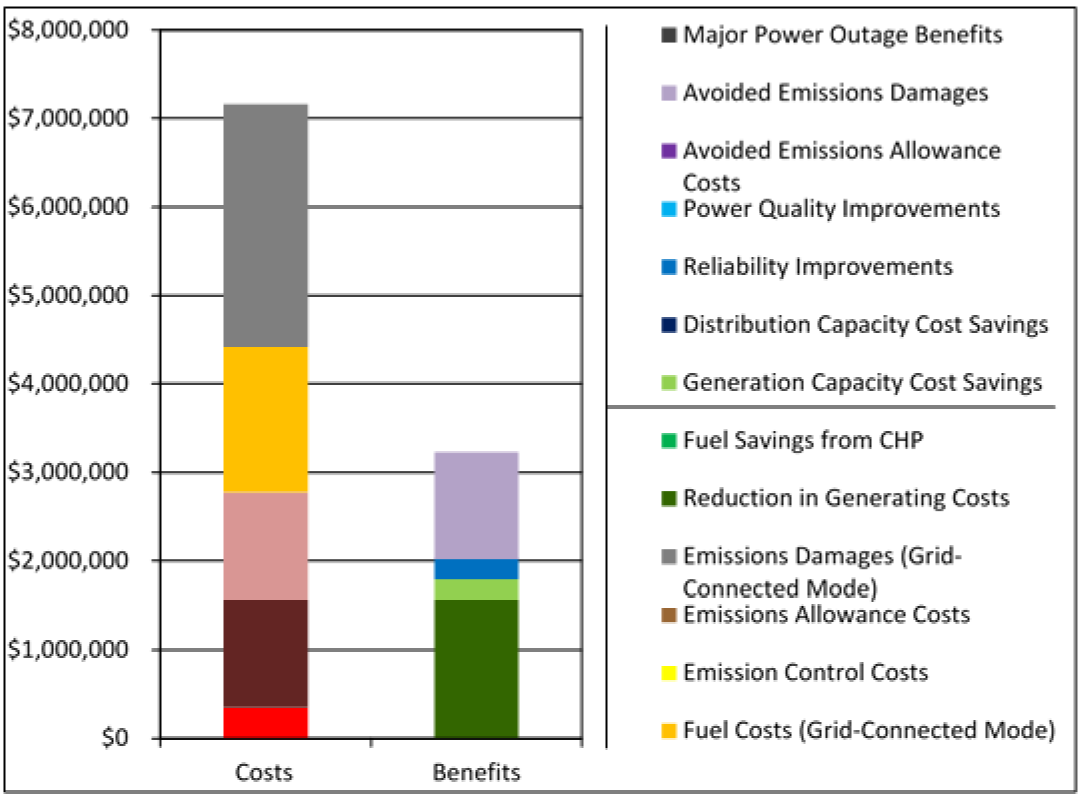

Table 36. Detailed BCA Results, Scenario 1

(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	$350,000	$30,900
Capital Investments	$1,210,000	$106,000
Fixed O&M	$1,210,000	$107,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$1,640,000	$145,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$2,740,000	$179,000
Total Costs	**$7,160,000**	
Benefits		
Reduction in Generating Costs	$1,560,000	$138,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$229,000	$20,200
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$227,000	$20,000
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$812	$72
Avoided Emissions Damages	$1,210,000	$78,700
Major Power Outage Benefits	$0	$0
Total Benefits	**$3,230,000**	
Net Benefits	**-$3,390,000**	
Benefit/Cost Ratio	**0.5**	
Internal Rate of Return	**n/a**	

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 $350,000. The present value of the project's capital costs is estimated at approximately $1.2 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 (communication cabling) for the microgrid; the new 300 kW natural gas unit; the 100 kW photovoltaic array; and the power lines needed to distribute the electricity the microgrid would generate. Operation and maintenance (O&M) of the entire system would be provided under fixed price service contracts, at an estimated annual cost of $107,000. The present value of these O&M costs over a 20-year operating period is approximately $1.2 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 generators. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the Project Team and projections of fuel costs from New York's 2015 State Energy Plan (SEP), adjusted to reflect recent market prices.[55] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $1.6 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 damages attributable to emissions from the natural gas generators are estimated at approximately $179,000 annually. The majority of these damages are attributable to the emission of CO_2. Over a 20-year operating period, the present value of emissions damages is estimated at approximately $2.7 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 Moreau'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 $1.6 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. These reductions in demand for electricity from bulk energy suppliers would also result in avoided emissions of CO_2, SO_2, NO_x, and particulate matter, yielding emissions allowance cost savings with a present value of approximately $800 and avoided emissions damages with a present value of approximately $1.2 million.[56]

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.[57] 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 be approximately 270 kW per year (the team estimates no impact on distribution capacity).

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

[56] 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.

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

Based on this figure, the BCA estimates the present value of the project's generating capacity benefits to be approximately $230,000 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 New York Independent System Operator (NYISO). Whether NYISO would select the project to provide these services depends on NYISO's requirements and the ability of the project to provide support at a cost lower than that of alternative sources. Based on discussions with NYISO, it is our understanding that the 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 $20,000 per year, with a present value of approximately $230,000 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:[58]

- System Average Interruption Frequency Index – 0.96 events per year.
- Customer Average Interruption Duration Index – 116.4 minutes.[59]

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.[60] 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.

[58] www.icecalculator.com.
[59] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for National Grid.
[60] 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 0.5; i.e., the estimate of project benefits is approximately 50 percent 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.[61,62]

As noted above, the Town of Moreau's microgrid project would serve eight specific facilities in addition to the residential cluster: the Town Clerk's Office; South Glens Falls Fire Company (Station No.2); Moreau Family Health; Wallace Supply Co, Inc.; Landmark Motor Inn; a Hess Express Gas Station; the Saratoga County Sheriff's Office (Moreau Substation); and the Moreau Town Annex Building. The project's consultants indicate that at present, only the Town Clerk's Office and the South Glens Falls Fire Company are equipped with backup generation; the level of service these units can support is 100 percent of the ordinary level of service at these facilities. Operation of these units costs approximately $170 per day. Should these units fail, all eight facilities could maintain operations by bringing in portable diesel generators with sufficient power to maintain all services. The operation of these units would cost approximately $6,000 per day. In the absence of backup power – i.e., if the backup generators failed and no replacements were available – the facilities would experience the loss in service capabilities detailed in Table 37.

[61] 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.

[62] 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 37: Loss of Service Capabilities

Table provides the percent loss in service when backup power is not available by facility.

Facility Name	Percent Loss in Services When Backup is Not Available
Town of Moreau Town Clerk's Office	50%
South Glens Falls Fire Company	50%
Moreau Family Health	75%
Wallace Supply Company Inc.	75%
Landmark Motor Inn	75%
Hess Express Gas Station	75%
Saratoga County Sheriff's Office	50%
Moreau Town Annex Building	50%

The information provided above serves as a baseline for evaluating the benefits of developing a microgrid. Specifically, the assessment of Scenario 2 makes the following assumptions to characterize the impacts of a major power outage in the absence of a microgrid:

- The Town Clerk's Office and the South Glens Falls Fire Company would rely on their existing backup systems, experiencing no loss in service capabilities while the backup system operates. If the backup generators fail, both facilities would experience a 50 percent loss of service.
- Moreau Family Health, Wallace Supply Company, Landmark Motor Inn, the Hess Express Gas Station, the Saratoga County Sheriff's Office, and the Moreau Town Annex Building would rely on portable generators, experiencing no loss in service capabilities while these units are in operation. If the portable generators fail, Moreau Family Health, Wallace Supply Company, Landmark Motor Inn, and the Hess Express Gas Station would experience a 75 percent loss in service effectiveness, while the Saratoga County Sheriff's Office and Moreau Town Annex Building would experience a 50 percent loss in service effectiveness.
- In all eight cases, the supply of fuel necessary to operate the backup generators would be maintained indefinitely.
- 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 impact of a loss in service at these facilities is based on the following value of service estimates:

- Town of Moreau Town Clerk's Office, a value of approximately $34,593 per day.[63]

[63] www.icecalculator.com.

- South Glen Falls Fire Company, a value of approximately $83 per day.[64]
- Saratoga County Sheriff's Office (Moreau Substation), a value of approximately $680 per day.[65]
- Moreau Family Health, a value of approximately $29,709 per day.[66]
- For Wallace Supply Company, Inc. and Landmark Motor Inn, a value of approximately $133,401 per day.[67]
- Hess Express Gas Station, a value of approximately $8,824 per day.[68]
- Moreau Town Annex Building, a value of approximately $5,862 per day.[69]

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for the facilities of interest is approximately $213,000 per day.

Summary

Figure 8 and Table 38 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 13.7 days per year without power. If the average annual duration of the outages the microgrid prevents is below this figure, its costs are projected to exceed its benefits.

64 Based on FEMA methodology, 100% probability of an outage, with an outage duration of 1 day.
65 Based on FEMA methodology, 100% probability of an outage, with an outage duration of 1 day.
66 www.icecalculator.com.
67 Ibid.
68 Ibid.
69 Ibid.

Figure 8. Present Value Results, Scenario 2

(Major Power Outages Averaging 16 Days/Year; 13.7 Percent Discount Rate)

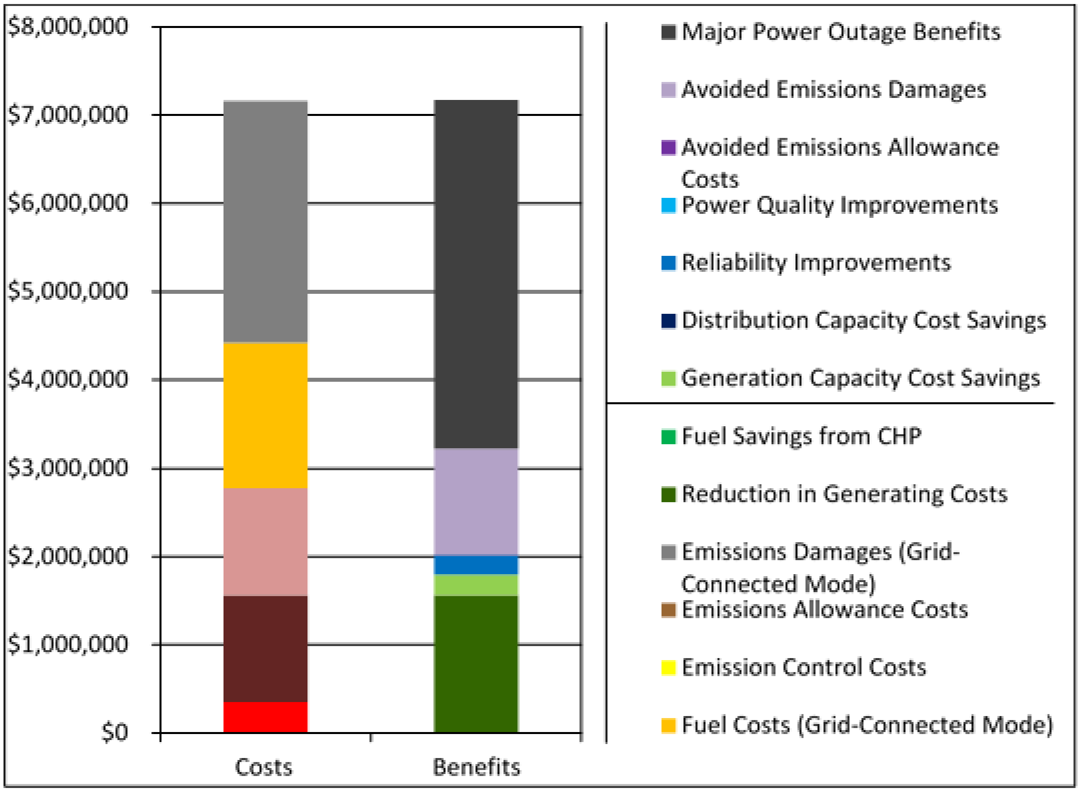

Table 38. Detailed BCA Results, Scenario 2

(Major Power Outages Averaging 13.7 Days/Year; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value Over 20 Years (2014$)	Annualized Value (2014$)
Costs		
Initial Design and Planning	$350,000	$30,900
Capital Investments	$1,210,000	$106,000
Fixed O&M	$1,210,000	$107,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$1,640,000	$145,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$2,740,000	$179,000
Total Costs	**$7,160,000**	
Benefits		
Reduction in Generating Costs	$1,560,000	$138,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$229,000	$20,200
Transmission & Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$227,000	$20,000
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$812	$72
Avoided Emissions Damages	$1,210,000	$78,700
Major Power Outage Benefits	$3,950,000	$351,000
Total Benefits	**$7,180,000**	
Net Benefits	**$15,100**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**11.1%**	

The Project Team assumed an electricity sales price of $0.073 per kWh in Moreau. This is the supply cost for National Grid, the average amount spent by National Grid 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 National Grid grid. In Moreau, the Capital LBMP is $38.22 per MWh[70], or $0.038 per kWh, a more than 47% 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

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

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.

5. Summary and Conclusions

5.1 Lessons Learned and Areas for Improvement

The lessons learned from the Moreau microgrid feasibility study are divided into two parts. The first part in Section 5.1.1 highlights Moreau-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 Moreau Lessons Learned

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

The development of the microgrid proposal in Moreau was somewhat unique in that the buy-in from the utility came early on in the process and allowed for a more robust conversation about what might be possible. Whereas many of the utilities were either noncommittal or content to message what they might not allow, National Grid also suggested what they might be interested in. Their position that no 3rd party would be permitted to operate control infrastructure or any part of the distribution system is consistent with each of the IOUs, however they suggested that they would consider owning the new control infrastructure and operating the microgrid. Outside of the Project Team's muni community, this was a first and provided a foundation for more concrete ownership and operational recommendations in the previous section. The Team's proposal of a fully utility-operated microgrid with silent DERs ownership was a direct outgrowth of National Grid's willingness to consider the ownership of control components and active involvement in the project.

Active utility involvement does not mitigate all issues, however. In Moreau, there is an excess of hydropower on the nearby rivers, and a natural choice for reliable and renewable baseload generation for a microgrid. The complication in connecting these otherwise useful generation assets is multiple. First, the distance between the dams and any given set of critical facilities may be significant; in Moreau it is many 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 small scale of the Moreau proposal, both options are simply infeasible from a cost perspective and the latter does little to enhance electric resilience. The larger the microgrid footprint becomes, the less redundant and resilient it is. The second issue in connecting the hydropower facilities is the incongruent voltage in the generator connected feeders and the feeders upon with the microgrid is proposed. This voltage step down requires transformers that further add to the cost, and couple with the distance, render hydropower connection infeasible.

Moreau, like many other communities, is constrained by its relatively low density: desired critical loads are often in distant locations and the adjacency found in urban or dense suburban areas is lacking. Such conditions require more control infrastructure, more intermediate load pickup, and the feeders are more likely to have downstream loads, rendering economic islanding impossible. Each of these conditions adds costs or strips revenue opportunities. The Moreau proposal connects two clusters of critical facilities into a singular microgrid, picking up several detached homes that are between the two on the feeder. While these extra loads are presumed to be fairly limited, there is no way to access load information and incorporate it into the sizing of the generation assets. The Project Team does not know if they have electric heating or cooling, the extent of electric appliances, or if there is particularly energy intensive equipment at the residences. In the aggregate, best-estimates may significantly undercount loads and could impact the integrity of the microgrid during islanded peak demand.

Lastly, many community microgrids are driven by particularly engaged local government officials who see the merit in expanding clean and resilient power supplies. Unfortunately for the continuity of such efforts, electoral governance is fickle in nature and officials may lose their elections in the midst of a project or study. The Project Team's main point of contact with the community in Moreau was a Councilman, however he lost his election in November and the Project Team understands that the newly elected leaders are not as engaged with or interested in the microgrid as our community liaison. While governance switches are a fact of project development, they can impede the process to the detriment of a successful implementation.

In comparison to working with a municipal utility, working with the investor-owned National Grid was a more time-intensive process. As a utility with a large footprint, customer base, and transmission and distribution network, National Grid has many issues to manage that require its attention, among which microgrids and NY Prize were just one. However, National Grid 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 National Grid 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. Moreau has sufficient natural gas availability to support natural gas-fired generation within the microgrid, but the electrical infrastructure is not ideal. While there are several, included facilities on a single feeder, they are not adjacent nor at the end of the feeder; this necessitates unquantified pickup loads and yields an inability to economically island. Nearby generation that appears sufficient and connectable is also at the mercy of the electrical infrastructure, and unfavorable feeder structures can quickly render otherwise exceptional generation useless to the microgrid.

Lastly, 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 or thermal energy sales if there is a proximate off-taker. Moreau does not have a proximate thermal off-taker and, therefore, there is no CHP proposed.

Financial. Across the portfolio of communities managed by the Project Team, natural gas availability and thermal 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 or other thermal energy; 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 Public Service Commission 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 Moreau, support from the utility for this effort has been robust and the community has been highly engaged, notwithstanding the electoral changes that saw our community liaison lose his position. In other communities, as in Moreau, the Project Team has been in regular contact with elected officials; this type of engagement is necessary to not only build support among prospective facilities but also to engage on ownership models, generation options, and other considerations that will directly affect the feasibility of the proposal. In those communities that are more removed from the process it is difficult to make firm recommendations, and the Project Team runs the risk of suggesting solutions that are, for whatever reason, unpalatable to the community.

Scalability. Scalability is governed by three factors. 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. The lack of voltage congruence was a key consideration in the Moreau proposal. Second, widespread AMI infrastructure makes expansion far less complicated and allows for the selective disconnect of facilities that are not microgrid participants. Moreau's microgrid is not an AMI remote disconnect based design; however, the utility of AMI is evident in other projects in the Project Team's portfolio. Lastly, the larger the microgrid grows, the more switches and controls are need to be installed, connected, and maintained for smooth islanding and grid-reconnect processes. In the aggregate, such infrastructure is costly and does not provide many direct returns. Utilities are also likely to push back if the microgrid grows to occupy significant portions of their infrastructure. To that end, the Project Team has worked diligently with the local utilities to find acceptable footprints that meet the goals of NYSERDA and respect the operational concerns of the utilities.

5.1.3 Stakeholder Lessons Learned

Developers. Some 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 thermal 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, including National Grid in Moreau, were uniformly 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. National Grid, 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 requires 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 kilowatt hour (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 Moreau

Critical and important facilities in the Town of Moreau 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 provided a summary outbrief and recommended path forward in a call with the community on February 25, 2016.

5.2.3 Benefits to Residents in and around Moreau

Residents of Moreau 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 Moreau 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 Moreau 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 Moreau microgrid is technically feasible and financially infeasible absent significant subsidies. This document details the capabilities of the microgrid, its primary technical design, the commercial, financial, and legal viability of the project, and the costs and benefits of the microgrid. The microgrid meets all of the NYSERDA required capabilities and most of its preferred capabilities.

Major challenges include working with National Grid 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. However, unfavorable project economics may render the project infeasible to pursue without a significantly expanded footprint and opportunity for greater generation and loads.

The proposed Moreau 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 National Grid 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.

Path Ahead

Beyond New York Prize, Moreau has several options available to improving energy resilience in the community through energy efficiency, distributed energy resources, and advanced technology such as microgrid controllers. Moreau has done well to implement energy efficiency programs in the community and this is always the first line of energy resilience.

One of the primary hurdles faced by Moreau in this feasibility study is the low-density nature of the community; there are simply very few, if any, critical masses of load that have an appropriate facility mix and feeder structure to support a cost effective microgrid implementation. Moreau has an industrial area that they are working to populate north of the microgrid footprint; if this comes to fruition the potential mix of relatively heavy loads may make the case for a formal microgrid in that location. The lack of immediate microgrid potential does not mean that distributed energy resources, which may exist without microgrid controls and switches, is infeasible in the community. Large solar generation on municipality-owned land, coupled with purchase agreements guaranteeing prices for a decade or more, would move Moreau further along towards a less costly and more resilient energy future. Small roof-mounted solar across the community would enhance collections of individual homes and, if coupled with increasingly cost effective battery storage, could provide a significant energy resource within the community. In addition, the proposed natural gas generator may be installed as currently sized, or decreased to match a single facility's load, to support baseload electricity demand. The levelized cost of production is competitive with retail prices from the grid, and provides for resilient, on-site generation. Either of these generation solutions can be implemented without the expense of a full microgrid control infrastructure.

The issue of connecting the nearby hydroelectric facilities is complex. Without large, dedicated loads there is no value proposition in extending the medium voltage feeders that connect to the dams, given the cost and complexity. The community in Moreau is engaged and eager to move forward with energy resilience solutions, and the Project Team believes that this feasibility study provides direction to help meet that objective.

Appendix

Metering data for typical 24-hour load profiles were provided by National Grid. 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. The Project Team was unable to find *interval* data for National Grid loads, so the team used a simulator to profile typical 24-hour load curves for each facility. The load profiles for all Moreau facilities are simulated.

REDACTED PER NDA WITH NATIONAL GRID