29 - Town of Mamaroneck

Notice

Town of Mamaroneck Microgrid Feasibility Study

Microgrid Project Results and Final Written Documentation

Prepared for:

New York State Energy Research and Development Authority (NYSERDA)
Jim Hastings, Project Manager
17 Columbia Circle
Albany, NY 12203-6399

Prepared by:

Booz Allen Hamilton Inc.
8283 Greensboro Drive
McLean, VA 22102

Date Submitted: March 31, 2016

Contract Number: 65093, Task 5

Points of Contact Authorized for the Town of Mamaroneck Microgrid Study:

Michelle Isenhouer Hanlin
1550 Crystal Drive, Suite 1100
Arlington, VA 22202
Phone: 717-501-8509
Email: isenhouerhanlin_michelle@bah.com

Stephen V. Altieri
740 West Boston Post Road
Mamaroneck, NY 10543
Phone: 914-381-7810
Email: SAltieri@townofmamaroneck.org

Notice

Abstract

Together with the Town of Mamaroneck, Booz Allen Hamilton has completed the feasibility study for a proposed community microgrid. This study summarizes the findings and recommendations, results, lessons learned, and benefits of the proposed microgrid. The Project Team has determined the project is feasible, though not without challenges. The commercial and financial viability of the project have been analyzed and are summarized in this document. The Mamaroneck microgrid project faces the challenge of high capital costs, but it benefits from the relatively high local electricity prices. The proposed natural gas and solar generation will provide a steady source of clean generation in Mamaroneck while lessening dependence on existing diesel backup generation. In addition, the Mamaroneck microgrid provides an ideal opportunity to explore the viability and interoperability of a community microgrid in a suburban, investor-owned utility (IOU) footprint. Many of the takeaways of the feasibility study may be generalized across the spectrum of the NY Prize and community microgrids.

Keywords: NY Prize, NYSERDA, distributed energy generation, energy resiliency, clean energy, DER, Mamaroneck

Contents

Figures

Tables

Acronyms and Abbreviations

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

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
SPV	Special Purpose Vehicle
TCP/IP	Transmission Control Protocol/Internet Protocol

Executive Summary

Booz Allen Hamilton was awarded a contract by the New York State Energy Research and Development Authority (NYSERDA) through its New York Prize initiative to conduct a Feasibility Study of a community microgrid concept in the Town of Mamaroneck. This report 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. Our design demonstrates the Town can improve energy resiliency with intentional and emergency island mode capabilities, stabilize energy prices with distributed energy resource (DER) assets, and comply with the greater New York Reforming the Energy Vision (REV) by constructing 1.625 megawatts (MW) of clean energy generation capability. The study concludes the technical design is feasible.

The Mamaroneck microgrid project will tie together three critical (per NYSERDA's definition) and important facilities into a community microgrid. Table ES-1 lists all the facilities under consideration for the microgrid concept at this time, Table ES-2 lists the proposed and existing generation assets, and Figure ES-1 shows their locations in the Town of Mamaroneck.

Table ES- 1. Prospective Microgrid Facilities

Table lists the facilities in the Town of Mamaroneck's proposed microgrid.

Name	Description	Address
F1	Sarah Neuman Nursing Facility	845 Palmer Ave
F2	Mamaroneck High School	1000 West Boston Post Rd
F3	Town Center/Police Department Complex	740 West Boston Post Rd

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:

- An existing 200 kilowatt (kW) backup diesel generator at Sarah Neuman
- A proposed 1,500 kW natural gas-fired, continuous-duty, reciprocating engine located behind Mamaroneck High School
- A proposed 125 kW PV array system located behind Mamaroneck High School

The existing and proposed generation assets will supply 100% of the electricity requirements of the facilities in Table ES-1 during emergency outage conditions, providing relief to residents in and around the Town of Mamaroneck. The backup power provided by the microgrid will ensure shelter, municipal services, and elderly care all remain accessible in the event of a long-term grid outage. Both the natural gas generator and the photovoltaic (PV) array will operate in islanded and grid-connected mode, pushing electricity to the Consolidated Edison (Con Ed) grid via a long-term power purchase agreement (PPA). Generation assets and primary control infrastructure will be located on Town-owned land behind the Mamaroneck High School.

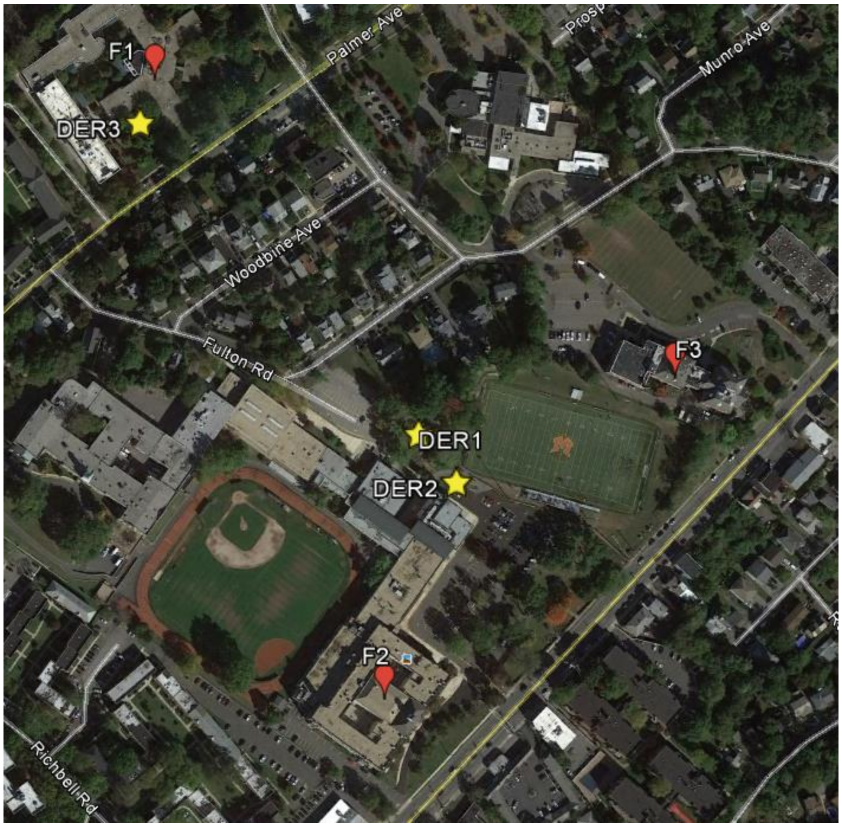
Table ES- 2. Microgrid Generation Assets

Table lists the existing and proposed DERs in Mamaroneck's proposed microgrid.

Name	Description	Fuel Source	Capacity (kW)	Address
DER1	New solar PV system at Mamaroneck High School	Sunlight	125	1000 West Boston Post Rd
DER2	New reciprocating generator at Mamaroneck High School	Natural Gas	1,500	1000 West Boston Post Rd
DER3	Backup generator at Sarah Neuman Nursing Facility	Diesel	200	845 Palmer Ave

Figure ES- 1. Map of Mamaroneck Microgrid Coverage Area

Figure displays a detailed map of the coverage area illustrating where the facilities are located relative to each other and the main streets within Mamaroneck.[1]



Mamaroneck and private investors will own the microgrid through a special purpose vehicle (SPV). The single SPV ownership model also affords Mamaroneck a seamless integration of generation, microgrid controllers, and distribution infrastructure and allows the SPV owners to capture the full suite of revenue streams, estimated at $820,000 per year. The model will maintain the current Con Ed billing and rate capture mechanisms, and revenues cover variable

[1] Map scale is approximately 1" = 500'

costs and required payments on capital expenditures before being proportionally distributed to SPV ownership.

The microgrid will incur initial capital costs of $3.3 million as well as operation, maintenance, and fuel costs totaling $820,000 per year. The Town of Mamaroneck has indicated interest in supporting a portion of the project costs potentially through a bond issuance, and private partners are expected to contribute the balance of the capital required. NY Prize Phase III funding is critical to this proposal's viability because the revenues generated by electric sales will not cover the full $3 million in capital expenditures.[2] Even with the NY Prize funding the project cannot recover all capital costs at a level of returns sufficient to entice private investment. If the project were to sell the power generated by the DERs at the retail rate directly to the customers the project could see positive financial returns but at both at Con Ed's supply charge (assumed by the Project Team) and at the location-based marginal price (assumed by IEc) the project is not financially viable.

In order to technically establish a microgrid in the proposed Mamaroneck footprint, a new distribution line between Mamaroneck High School and Sarah Neuman Center will need to be constructed. The line is necessary to connect two separate feeders while leaving intermediate and downstream loads undisturbed when the microgrid islands. While the new line is an added cost, it allows for islanding on a blue-sky days for economic or operational reasons and supports an eventual business model shift to a load-following, fully behind-the-meter entity.

The Mamaroneck microgrid concept, with new clean and renewable generation and the integration of existing energy resources, could provide the Town with an energy resilience solution that is technically sound and, with additional grant and incentive money may be financially viable. The ability to island three critical and important facilities will significantly bolster the resilience of the Town during emergencies and extended grid outages.

[2] The cost and revenue figures reflected in this report are based on the most recent and up-to-date information available to the Project Team. As a result of ongoing due diligence, the figures reported reflect the best available information on operations, maintenance, and capital costs of the microgrid infrastructure and generation assets. The changes are reflected here to provide the most accurate project characterization available and are within +/- 30% accuracy.

1. Introduction

The Town of Mamaroneck (Mamaroneck) is seeking to develop a community microgrid to improve energy service resiliency, accommodate distributed energy resources, stabilize energy prices, and reduce greenhouse gas (GHG) emissions. Working with Mamaroneck and Con Ed, a team from Booz Allen Hamilton (hereafter Booz Allen or the Project Team) designed a preliminary microgrid concept that connects three critical and important facilities to two new generation assets, a 1.5 MW natural gas generator and a 125 kW solar PV array, and an existing 200 kW diesel backup generator. The proposed microgrid serves physically disparate facilities, providing shelter and municipal services to the residents of Mamaroneck and surrounding areas. Section 2 of this document describes the configuration, the full scope of the proposed design, and its component parts in detail. 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.

Implementing a community microgrid that ties together these critical facilities to dedicated distributed energy resources would enhance the energy resilience of Mamaroneck. Depending on the price of electricity and the operational arrangement of the microgrid, it may also yield returns for the community and other investors. The construction of the microgrid will require significant capital at the outset for components like switches, lines, and control systems, as well as ongoing costs including fuel, operation, and maintenance. Permitting should not present a challenge because the majority of the construction projects, including the new generation assets and control center, will be on Town-owned land. Regulatory approvals to sell electricity to Con Ed will be standard; however, if the microgrid intends to operate strictly behind the meter, it must petition the Public Service Commission (PSC) for lightened regulation or inclusion as a Qualifying Facility (QF).

Section 2 of this document describes the configuration further. Section 3 provides an overview of the project's viability and Section 4 provides the cost benefit analysis information. Also in this document, the Project Team discusses the observations, findings, and recommendations from the entirety of the analysis. The Team explores avenues for further development, discusses project results, and shares lessons learned regarding configuration, capabilities, environmental and economic benefits, and implementation scenarios.

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

The Mamaroneck microgrid will improve the resiliency of the local electricity grid in emergency outage situations, accommodate distributed energy generation, stabilize energy prices during peak events, and reduce reliance on high emissions peaking assets during peak demand events. The Town of Mamaroneck experiences the usual range of extreme weather that faces the NYC area, including torrential rain, snow, wind, and flooding, all of which may impact the ability of the grid to safely, reliably, and efficiently deliver services to customers. Mamaroneck also enjoys the advantage of having three critical facilities located on two proximate feeder lines, which means the microgrid design requires only one new power line to connect the Sarah Neuman network to the high school/town hall complex. The three proposed facilities will be the only loads between proposed utility line breakers, rendering AMI remote disconnect unnecessary to enter island mode. [3]

When the larger grid loses power, the Mamaroneck microgrid will disconnect and supply power to critical facilities from connected generators. The microgrid will also be programmed to enter island mode when large fluctuations in voltage or frequency disrupt the power supply from the larger grid. Mamaroneck, like many towns in New York, has experienced several extreme weather events in recent years that affected power quality (Tropical Storm Lee, Hurricane Irene, and Hurricane Sandy). Flooding and falling branches destroyed power lines and interrupted delivery of electricity to the town's critical facilities. Many critical facilities in Mamaroneck (including two of the three facilities to be connected to the microgrid) do not have backup generation, so prolonged grid outages can create a potentially hazardous situation for all of the town's residents.

Assuming capacity factors of 85% for the NG reciprocating generator and 14% for the solar PV array,[4] the Project Team estimates that the microgrid's main DERs will generate an average of approximately 1.3 MW of electricity throughout the year. Although Mamaroneck is not currently considered a critical congestion point on the larger New York State grid, this generation capacity will reduce the amount of current that must be transmitted to the area from the larger grid.

The Town of Mamaroneck provides a unique opportunity to examine the prospects of a replicable, modular microgrid solution located just outside New York City. New York State has experienced severe longstanding congestion at critical points on the transmission system linking upstate and downstate New York, some of which could be eliminated by investing in distributed energy generation and microgrids with intentional island mode capability. The project could therefore serve as a model for the myriad coastal towns and critical congestion points in the area.

[3] There are no intermediate loads.
[4] Based on the NREL PV Watts Calculator.

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

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

The following section demonstrates how the design concept meets the required capabilities and select preferred capabilities provided by NYSERDA in the Statement of Work (SOW) 65093.

2.2.1 Serving Multiple, Physically Separated Critical Facilities

At this stage of the study, the Town of Mamaroneck and the Booz Allen team, in cooperation with Con Ed, have identified three critical facilities to be served by the microgrid, including a school/evacuation center, town buildings, and health centers. See Table ES-1 for a full list of prospective critical facilities to be tied into the microgrid.

The proposed microgrid footprint occupies approximately 40 acres in Mamaroneck. Loads will be interconnected via two new medium voltage power lines. Facilities will communicate over Con Ed'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 allow remote monitoring and control of distributed devices, regardless of manufacturer. The microgrid design is flexible and scalable in order to accommodate future expansion and technologies.

2.2.2 Limited Use of Diesel Fueled Generators

A natural gas-fired reciprocating generator will serve as the microgrid's primary energy source. As a comparatively low-emission, highly reliable fuel, natural gas is an ideal source of energy for the proposed community microgrid. Electricity from the 125 kW solar PV array will supplement energy from the reciprocating generator. The solar array will operate at maximum capacity during the summer and will offset some of the natural gas generator's emissions.

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 and automatically shed non-critical loads as needed to maintain stable and reliable power flow. In grid-connected mode, the microgrid will optimize the use of available assets to reduce energy costs when possible and export to the Con Ed grid when economic and technical conditions align.

The proposed generation assets will operate continuously in grid-connected mode, reducing local dependence on grid-supplied power. In island mode, the solar PV array will supplement the reciprocating generator's output to meet critical loads. The MCS will bring the backup diesel generator on-line as necessary to ensure a steady power supply.

2.2.4 Intentional Islanding

The microgrid will intentionally switch to island mode when doing so results 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.

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.

2.2.5 Resynchronization to Con Ed Power

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

An additional breaker at the point of common coupling (PCC) is required to connect the new microgrid generation. 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 NYPSC interconnection standards. Table 1 outlines the most significant state interconnection standards that apply to this microgrid project. Con Ed customers connecting to the grid via distributed energy resource projects must follow the same New York State Standard Interconnection Requirements detailed in Table 1.

Table 1. 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-

Standard Category	Description
	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 Hertz (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 main generation source for the community microgrid located behind the high school on 1000 W. Boston Post Road. The Town's existing natural gas supply line at this location is a 20 inch High Pressure line with sufficient volume and pressure that can support 24/7 continuous operation.

The Project Team was unable to determine the Sarah Neuman Center's diesel storage capacity. The diesel generator most likely will be unable to operate continuously because it is limited by the amount of diesel fuel on hand.

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 Mamaroneck. The new automation solution proposed in this report will serve as a protocol converter to send and receive all data available to the operator over Con Ed's WAN using industry standard protocols such as DNP3 as well as OPC, Modbus, 61850, 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). Synchronization is key to maintaining a stable power network—the larger grid also requires the constant synchronization of energy sources, but its comparatively higher electrical and mechanical inertia filters out most fast dynamics. In contrast, the microgrid will be quite sensitive to fluctuations in load or generator output. It is therefore crucial to constantly monitor and regulate generator output against aggregate load in real time.

2.2.10 Load Following and Frequency and Voltage Stability When Islanded

The microgrid's control scheme in islanded mode is quite similar to that of the larger transmission system. The system maintains frequency by controlling real power generation and regulates voltage by controlling reactive power availability. 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 the frequency and voltage stability. The Project Team will consider these factors and develop a microgrid design that accounts for them in the next phase of the NY Prize competition. The comparatively small size of the microgrid introduces new, fast, and dynamics-related problems that will be carefully studied during the engineering design phase.

In islanded mode, the MCS will maintain control of the generating units to maintain voltage and frequency. In addition, the MCS will combine load shedding and generation control to maintain the demand supply balance.

2.2.11 Diverse Customer Mix

At present, the microgrid design includes three facilities: a high school, a local government building complex, and a healthcare center. Even though this customer mix is not widely diverse, these facilities provide vital and beneficial services to the Town of Mamaroneck during outages. It may be possible for more facilities to be connected to the microgrid in the future. Table 2 lists all the facilities currently being considered in the microgrid concept design, and Figure 1 shows them on a map.

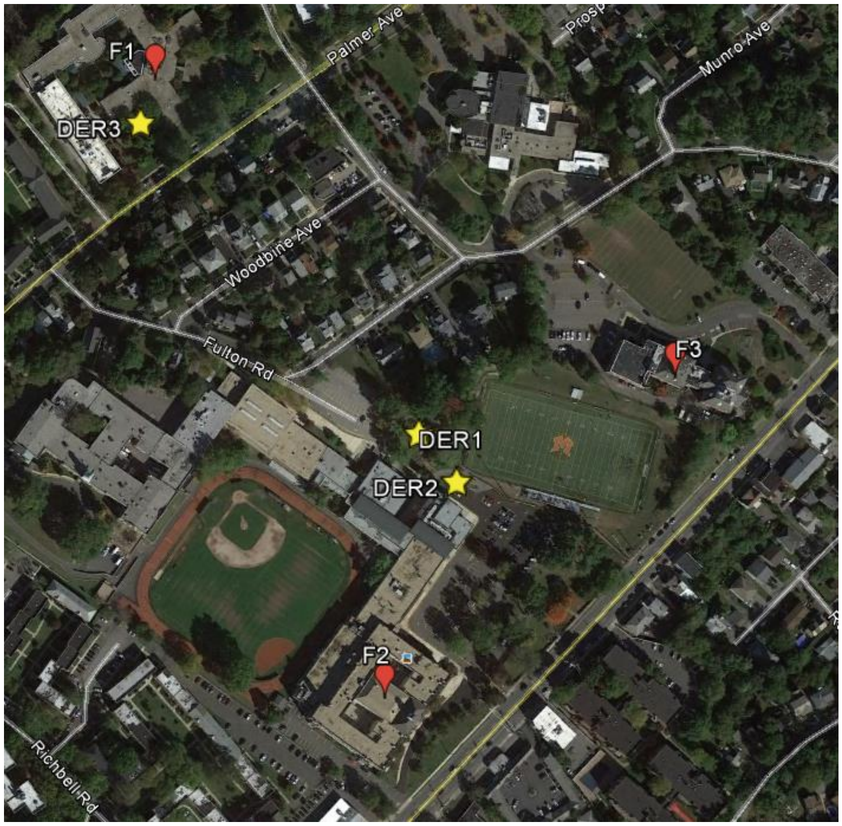
Table 2. Town of Mamaroneck List of Prospective Microgrid Facilities

Table lists properties, addresses, and classifications for each facility proposed for the Mamaroneck microgrid.

	Property	Address	Classification
1	**Sarah Neuman Center**	845 Palmer Ave	Health
2	**Mamaroneck High School**	1000 West Boston Post Rd	Public
3	**Town Center and Town Police**	740 W. Boston Post Rd	Public

Figure 1. Map of Microgrid Coverage Area

Figure provides a detailed map of the approximately 40 acre coverage area illustrating where all three facilities are located relative to each other and the main streets within Mamaroneck.



2.2.12 Resiliency to Weather Conditions

The Town of Mamaroneck is exposed to the normal range of weather conditions that affect the Northeastern United States. Extreme weather events include (but are not limited to) torrential rain, snow, and wind that could cause falling objects and debris to disrupt electric service and damage equipment and lives. In addition, as a shore community, Mamaroneck is subject to hurricanes and flooding, including recent disruptions due to 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. The reciprocating generator, the microgrid's principal generation asset, will be protected from extreme weather by a new enclosure or will be placed inside an existing high school facility. If constructed overhead, the new express cable may be exposed to severe weather—however, burying the line underground may represent a crippling capital cost. The Project Team will weigh the benefits and costs of overhead and underground line placement during the next phase of the NY Prize competition.

2.2.13 Black-Start Capability

The proposed reciprocating generator will be equipped with black-start capabilities. If the Mamaroneck grid unexpectedly loses power, the MCS will initiate island mode by orchestrating the predefined black-start sequence. The natural gas generator will require an auxiliary source of DC power to start multiple times in case of failure. It will ramp up to 60 Hz and prepare to supply each of the microgrid loads in sequence. After the generator is online and providing a stable power supply, the MCS will synchronize output from the solar array and bring it online.

2.2.14 Energy Efficiency Upgrades

Energy efficiency (EE) is critical to the overall microgrid concept. The Town of Mamaroneck formed a Sustainability Collaborative in 2012, which identified existing sustainability measures (including EE) that had been taken as well as future initiatives that could be implemented. As part of this initiative, the Town Center and high school have undergone one round of Energy Savings Performance Contracts.

An additional objective of the Sustainability Collaborative is the development of a sustainability plan. Municipalities in the state can take a Climate Smart Communities Pledge, a New York State initiative that helps address ten sustainability focus areas. As a result of prioritizing sustainability initiatives, two initiatives that include EE measures were in the top six, including adopting a green procurement policy and adopting a green building code for residential and/or commercial construction. While these are part of the highest ranked initiatives, all of the measures are to be implemented at the Town's discretion.

The Project Team estimates the reduction potential for the three facilities to be approximately 75 kW. The project will incorporate Con Ed EE programs to reduce load at existing facilities and will seek to qualify microgrid facilities for NYSERDA funded EE programs.

Applicable EE programs include:

- Con Ed programs for Small Businesses: Con Ed will perform a free energy survey and will pay for up to 70% of recommended customized EE upgrades. Any small business with central air conditioning is also eligible for installation of a free smart thermostat. The Sarah Neuman Center and Town Hall complex may qualify for these programs.
- Con Ed programs for Commercial and Industrial Facilities: Con Ed will pay up to 50% of the cost of an energy survey. These programs also offer equipment upgrade incentives and enhanced incentives for new EE technology. The high school may qualify for these programs.
- NYSERDA Commercial Existing Facilities Program: This program offers facilities two options for participation. Under the pre-qualified path, NYSERDA will compensate participating facilities up to $60,000 for qualifying retrofits/EE upgrades such as lighting, commercial refrigeration, heating and air conditioning, and gas equipment upgrades. Facilities can also apply for custom incentives under the performance-based path—if a facility wishes to participate in this path it is crucial to involve NYSERDA early in the planning and development process.

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.

Considering the logical controllers (IEDs) will be located at or near loads, the distributed equipment will take the IT system to the "edge," 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), used to 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

The Town of Mamaroneck does not have AMI meters installed throughout its coverage area. Smart meters are not required for the Mamaroneck microgrid because the control sequence is performed at the feeder and facility-level.

2.2.19 Distribution Automation

The automation solution outlined in this study 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

The Project Team's analysis of battery storage technologies found their cost to be prohibitively high. Despite this, the MCS will be equipped with the capability to fully utilize and optimize the storage resources—including charging and discharging cycles for peak demand shaving—in case the town reevaluates its options in the future. The price of battery storage technology is constantly decreasing, and by "stacking" different uses (i.e., microgrid resiliency, frequency regulation, and PV integration), microgrid owners may soon be able to achieve a competitive levelized cost of storage.[5]

2.2.21 Active Network Control System

The microgrid will be under continuous and close monitoring and control when it operates in either grid-connected or islanded mode. Both monitoring and control will be decomposed in 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 on the microgrid 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 Town's fiber optics backbone partitioned using gigabit Ethernet switches.

2.2.22 Demand Response

The Mamaroneck microgrid will be technically able to enter island mode to participate in demand response (DR) programs, but doing so removes its generation capacity as well as load off the larger grid. Because its generators will operate nearly continuously throughout the year, entering island mode may not qualify as an eligible change from baseline operation. In other words, the microgrid's generation assets will provide a constant level of load reduction, but it is unlikely consistent load reduction will qualify for Con Ed's DR programs. In the event that Con Ed changes their policies to allow participation in DR programs by entering island mode (to incentivize the resiliency provided by microgrids), the microgrid can seamlessly transition to island mode when commanded to do so by Con Ed.

In the event that Con Ed does not accept island mode as an eligible method of participation in DR programs, the microgrid may still be able to participate by ramping up the output of spinning generators or curtailing flexible loads. Con Ed offers two options for participation in DR programs: voluntary participation (participants can choose to reduce load during an event) and required load reduction (participants bid capacity and are penalized if they fail to reduce load by the promised amount). The generation assets in the proposed microgrid are sized to approximately match the Town's peak demand—the microgrid therefore cannot guarantee that additional capacity will always be available. Therefore, the microgrid's participation in DR programs will likely be limited to the voluntary option.

Ultimately, DR and ancillary service programs can provide strong revenue streams. However, current policies do not incentivize the movement of both load and associated generation off the macrogrid.

2.2.23 Clean Power Sources Integration

The proposed energy sources, natural gas and solar energy, will provide the microgrid with reliable, relatively low-emission electricity. More detailed methods to capture and convert energy by electric generators or inverters will be explored at a later time. The Project Team is still reviewing possible clean power sources.

---

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

2.2.24 Optimal Power Flow

As recommended by Con Ed, the proposed community microgrid is fairly small, with only three facilities and three generation resources. If the microgrid owners negotiate a long-term Power Purchase Agreement with Con Ed, the Project Team expects the non-diesel generation assets to operate continuously throughout the year. In the event that the microgrid can meet the criteria for a qualifying facility, the MCS will optimize output for the purpose of load following for the facilities included in the microgrid footprint. 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 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 inverter will usually operate at its maximum power point because there is no associated O&M cost. In some rare situations, the PV array might have to reduce its output for load following in islanded mode, to participate in frequency control, or if a business structure is pursued where the microgrid serves as a qualified facility and load following is required. In such situations, the control is almost exclusively local with the output set point communicated by the central controller. As with other renewable energy sources, power output depends on weather and time of day. The microgrid power management system includes high resolution solar forecasting, which will increase value by firming up the PV generation and smoothing out ramping. The MCS will fully integrate and optimize output from the new solar array at the high school.

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 NY Prize, the microgrid designer will perform protection studies that account for possible bidirectional power flows and low fault currents (which can occur when the microgrid is operating in island mode).

2.2.28 Selling Energy and Ancillary Services

It is assumed the microgrid will be permitted to back-feed through Mamaroneck's main substation into the broader Con Ed transmission system and will sell excess energy from the solar array and reciprocating generator to Con Ed.

Most lucrative NYISO ancillary service markets (such as the frequency regulation market) require participants to bid at least 1 MW of capacity. The microgrid's 1.5 MW reciprocating generator will be technically capable of participating in most ancillary service markets, but it will not reliably have 1 MW of capacity available for participation in these markets. Other ancillary service markets, such as spinning and non-spinning reserves, do not provide competitive payments to small scale generators like the 1.5 MW natural gas unit. The Project Team has concluded that the microgrid most likely will not participate in NYISO ancillary service markets unless the reciprocating generator can be expanded.

Overbuilding the reciprocating generator could provide microgrid owners with interesting options—microgrid owners could sell extra electricity capacity into NYISO frequency regulation or ICAP (installed capacity) energy markets. With one extra MW of generation capacity, the microgrid could also participate in the novel NYISO Behind the Meter: Net Generation program. At this time, initial analyses indicate it is not economically advantageous to size up the generation assets in Mamaroneck to participate in the ancillary service markets. Ultimately, the sale of power at retail and wholesale rates is both more lucrative (than having that excess generation idle) and more stable than ancillary service markets.

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 the continuous operation of the reciprocating generator and solar array and sale of energy under a custom long-term Power Purchase Agreement with Con Ed, or directly to the facilities if possible as outlined in the Appendix. Investors will receive revenue from electricity sales. 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 at the center of this feasibility study. The Project Team has engaged with all involved parties to understand their specific needs and constraints. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.3.

2.2.32 Demonstrate Tangible Community Benefit

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

2.3 Distributed Energy Resources Characterization (Sub Task 2.3)

As described above, the proposed microgrid includes two new DERs and one existing diesel generator in Mamaroneck. This section will discuss the benefits of the proposed resources and how they will meet the microgrid's objectives in greater detail.

2.3.1 Existing Generation Assets

The Mamaroneck microgrid will incorporate one existing diesel backup generator (as described in Table 3). Several factors must be considered when deciding whether or not an existing diesel back-up generator should be included in the microgrid. These include generator capacity, load following capability, reactive power generation control, functionality (whether it serves emergency power), and location with respect to the loads it is intended to serve. Finally, the use of diesel generators may not be ideal if an alternative clean generation asset is available. Construction of the 1.5 MW natural gas-fired unit and 125 kW solar PV array will greatly reduce the Town's need for diesel generation.

The existing diesel generator included in the microgrid is located at the Sarah Neuman Center (200 kW). This generator was selected for its ample generation capacity and ability to supplement the grid if the PV array is not able to produce enough power at a given time in islanded mode. Grid paralleling switchgear will be required at this unit to ensure it is capable of switching between parallel and island mode. The four-year-old Cummins (model DSHAC) generator is currently on a maintenance program. Specifically, the diesel generator is exercised weekly for one hour by Sarah Neuman Center maintenance staff, while the local Cummins dealer performs three four-hour maintenance tests per year. Although the diesel generator will be included in the microgrid, it is not intended for 24/7 continuous operation. Therefore, it will only be activated in islanded mode to support peak load demand and to serve the loads when either the natural gas-fired generator or PV arrays need to be taken off-line for maintenance.

Table 3. Existing Distributed Energy Resources

Table displays the DER name, technology, rating in kW, fuel, and address.

Name	Technology	Rating (kW)	Fuel	Address
Sarah Neuman Center	Diesel Generator	200 kW	Diesel	845 Palmer Ave

2.3.2 Proposed Generation Assets

The two proposed generation assets include a 1.5 MW natural gas-fired continuous duty reciprocating generator and a 125 kW PV array system, seen in Table 4. To avoid any ownership conflicts, both assets will be located behind the high school on municipally-owned land.

Table 4. Proposed Generation Assets

Table describes the gas-fired reciprocating generator and the solar PV. Included are their rating, fuel, and address.

Name	Technology	Rating (kW)	Fuel	Address
Natural Gas Recip.	Recip. generator	1500 kW	Natural Gas	Land behind 1000 West Boston Post Rd
PV Array	Solar	125 kW	N/A	Land behind 1000 West Boston Post Rd

2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics

The proposed design provides Mamaroneck with several additional energy resources. In grid-connected mode, the proposed PV array and natural gas-fired generator unit will operate in parallel with the main grid. In islanded mode, the PV array and natural gas-fired generator will supply the base load with supplementary power from the existing diesel generator available to meet peak loads. The natural gas-fired generator unit and diesel generator are capable of meeting the microgrid's demand during island mode, ensuring adequate power is available if the solar PV arrays are offline due to weather or time of day.

To avoid power supply disruptions and protect the microgrid generation assets from damage, the team has proposed equipment locations at elevated areas of the town not prone to flooding. In addition, the existing 20" natural gas pipeline that will feed the proposed natural gas-fired reciprocating engine is buried to protect it from severe weather. The team is still determining the best way to safeguard the generators from weather, but they will be protected from rain, snow, strong winds, or falling trees. At a minimum, the proposed natural gas reciprocating generator will be protected by a container.

The natural gas reciprocating generator 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 maintain demand and supply balance in island mode.
- Black start capability – the generators will have auxiliary power (batteries) required to start and establish island mode grid frequency. After the natural gas reciprocating generator has established stable power flow, the main microgrid controller will synchronize the solar array inverters to match the generator's frequency and phase.
- Conformance with New York State Interconnection Standards.[6]

2.4 Load Characterization (Sub Task 2.2)

The Project Team sized proposed DERs according to electricity demand data from relevant load points. The load characterizations below (see Table 8 and the Appendix) fully describe the electrical and thermal loads served by the microgrid based on metering data provided by Con Ed.

2.4.1 Electrical Load

The Project Team evaluated three primary electrical loads for the Mamaroneck microgrid: the Sarah Neuman Center (a healthcare facility that includes 301 residents), the Mamaroneck High School complex, and the Town Center and Town Police facilities. Con Ed provided the Project Team with twelve months of metering data for connected facilities (Jan-Dec 2014), as summarized in Table 5. The aggregate peak load in 2014 was 1.816 MW, and the monthly

[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*.

average was 690 kW. Typical 24 hour load profiles for each facility can be found in the Appendix.

Table 5. Mamaroneck's 2014 Microgrid Load Points

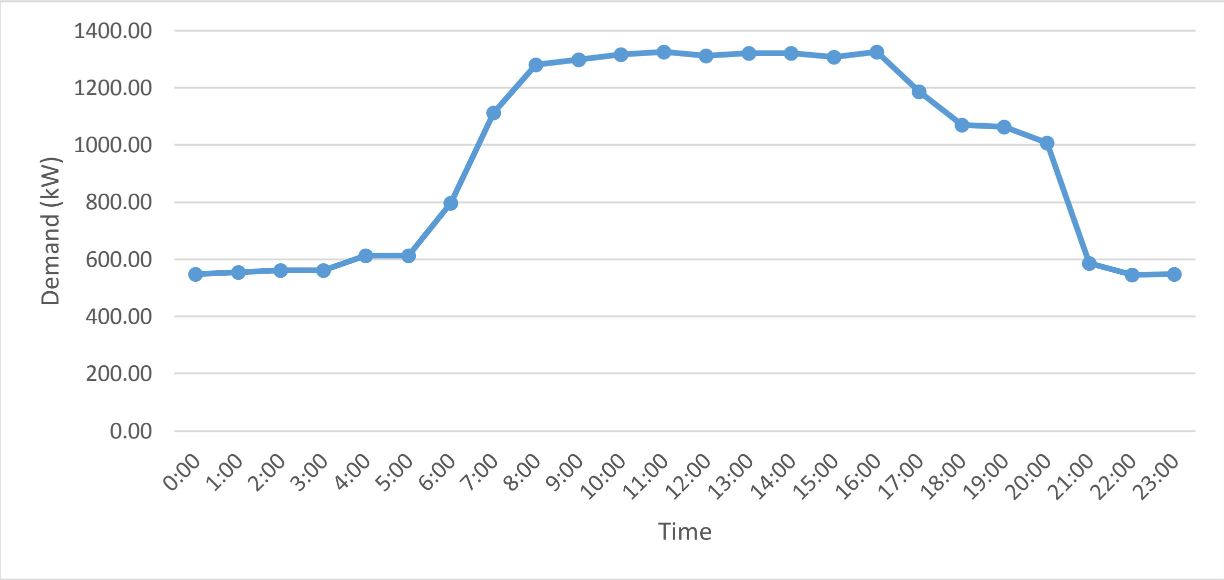
Table displays the microgrid electric demand in kW, the electric consumption in kWh, and the thermal consumption in million British Thermal Units (MMBTU).

REDACTED PER NDA WITH CON ED

Figure 2 provides a typical aggregate hourly load profile for Mamaroneck. Connected facilities consume significantly more energy in the day-time (08:00-18:00) compared to the night-time baseline. The solar array will operate at peak capacity during the daylight hours, providing maximum electricity when aggregate demand is highest. The proposed 1.5 MW reciprocating generator and 125 kW solar array should consistently meet microgrid demand without the need for supplemental backup generation. However, the existing 200 kW diesel generator will always be available during islanded operation. The natural gas-fired generator and solar array will need to go off-line for maintenance at various points throughout the year. Because the proposed reciprocating generator will provide the vast majority of the microgrid's power supply, the microgrid will need to rely on grid-supplied power when this generator goes offline for maintenance.

Figure 2. Typical 24-Hour Cumulative Load Profile

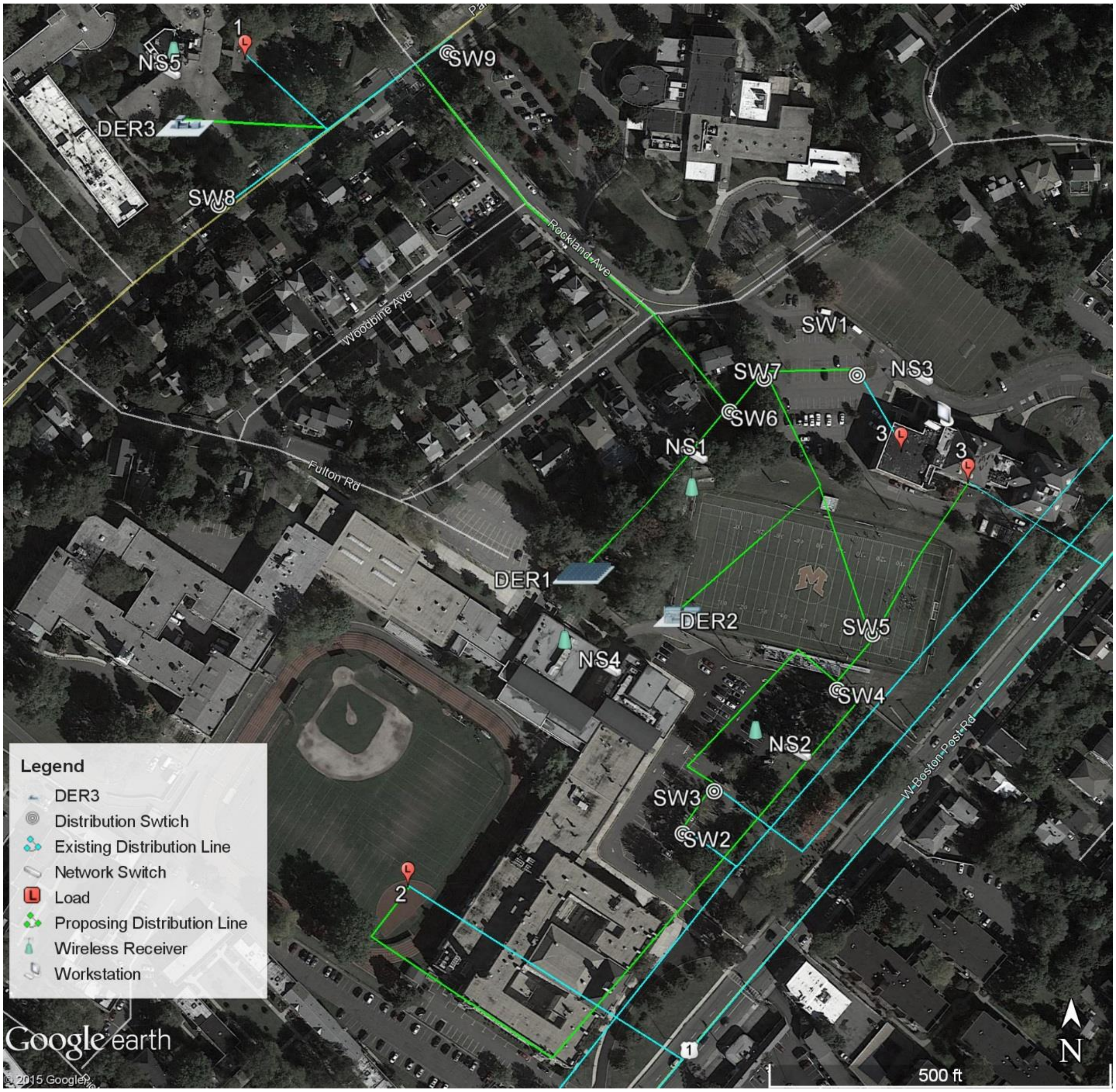
Figure illustrates the typical 24-hour cumulative load profile in which the system peaks in the afternoon; it uses varied samples from the 2014 Metering Data for the High School, Town Center and Town Police, and Sarah Neuman Center.



After extensive consultation with Con Ed representatives, the Project Team has determined that a new express run of cable line will be necessary to connect microgrid facilities. The design also includes two new pad mounted enclosures (PME) and one new automatic transfer switch (ATS) to reliably isolate loads and generation in islanded mode. Figure 3 provides an illustration of the proposed microgrid design and layout, including loads, switches, existing electrical infrastructure, and proposed electrical infrastructure.

Figure 3. Mamaroneck Equipment Layout

Figure shows microgrid equipment layout. Illustrated are distributed energy resources, distribution lines, load points, servers and workstations, network switches, and proposed distribution switches. OEM Generator Breakers for DER 2-3 and OEM Inverter Breaker for DER1 are not shown.



2.4.2 Thermal Consumption

The facilities to be connected by the proposed microgrid have minimal thermal energy demand. Therefore, the technical design does not include thermal energy production and offtake. In conducting the thermal load analysis, the team considered a previously completed study of cogeneration potential for the small thermal load (hot water only, no steam) at Sarah Neuman. The team concluded that the addition of combined heat and power (CHP) capability would add significant cost to the project design with minimal benefit. Any cogeneration would replace existing natural gas-fired boilers; thus, the overall cost and emissions savings would be minimal.

2.5 Proposed Microgrid Infrastructure and Operations (Sub Task 2.1)

The existing electric 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 Connected Parallel Mode

The microgrid will most often operate in grid-connected mode. In this mode, the proposed 1.5 MW gas-fired reciprocating engine generator and the proposed 125 kW PV array will operate continuously, selling power to Con Ed under a long-term PPA. Standard components will allow the microgrid to import power from the larger Con Ed grid or back-feed excess power when generation exceeds microgrid demand. These connections with Con Ed’s distribution grid will be maintained for reliability during grid-connected mode and to facilitate the sale of electricity to Con Ed.

If the larger grid experiences an emergency while the microgrid is connected, the parallel mode control scheme allows for the export of a predetermined amount of active and reactive power from microgrid DERs. By injecting power into the larger grid, the microgrid may be able to balance system frequency and voltage to avert an outage. If the 1.5 MW reciprocating generator has sufficient capacity, it will ramp up generation as necessary to fulfill the necessary power requirement.

2.5.2 Intentional Islanded Mode

The proposed energy management and control scheme in islanded (autonomous) mode will balance generation with microgrid demand and maintain adequate frequency, voltage, and power flow across all connected facilities (as described in Section 2.7.4). Islanded mode can be intentionally utilized during forecasted Con Ed grid outages or disturbances to maintain electricity supply for microgrid facilities. If operating in islanded mode qualifies the microgrid for participation in Con Ed DR programs, the microgrid control system (MCS) may also initiate island mode in response to signals from Con Ed. The system will manage the 1.5 MW natural gas-fired generator, 125 kW solar PV array, and existing 200 kW diesel back-up generator to match aggregate facility demand in real time. Because the output of the solar array is dependent upon weather conditions and time of day, the natural gas reciprocating generator and diesel backup generator will provide flexible real-time response. Refer to the simplified one-line diagram in Figure 4 for a detailed device representation showing generation assets and their utility interconnection points.

2.6 Electrical and Thermal Infrastructure Characterization (Sub Task 2.4)

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

2.6.1 Electrical Infrastructure

Electricity from Con Ed enters on West Boston Post Road from FDR-17W32 and connects to a proposed ATS and Pad Mounted Equipment (PME). It will then branch out to pick up the high school and Town Center load on Fulton Road. The microgrid design includes a new express line that will connect the Sarah Neuman Center to the Town Hall complex and high school. Another PME, located at or near the high school, will couple the proposed generation assets and act as bus bar to connect an express run of cable to energize the Sarah Neuman Center. The Sarah Neuman Center is currently on a separate “loop” (Con Ed’s term for one of their power flow distribution types). The proposed solution isolates the Sarah Neuman Center from that other loop, thereby making FDR-17W32 its primary feed. This is depicted in the one-line diagram below in Figure 4.

Use of the listed hardware, software, and resources must be synchronized to maintain stable and reliable operation and are outlined in Tables 6 through 8.

Table 6. Mamaroneck Distributed Switches Description

Table outlines all twelve distributed electrical switches with their description and status as new or requiring an upgrade.

Name	Description	New/Upgrade
SW1	Automatic Switch	Upgrade
SW2	Automated Transfer Switch	New
SW3	Automated Transfer Switch	New
SW4	Automated Transfer Switch	New
SW5	Automated Transfer Switch	New
SW6	Automatic PME	New
SW7	Automatic PME	New
SW8	Automatic Switch	New
SW9	Automatic Switch	New
SW10	OEM Inverter Breaker	New
SW11	OEM Generator Breaker	New
SW12	OEM Generator Breaker	New

Table 7. Mamaroneck Network Switch Description

Table outlines all five IT network switches with their description, status as existing or proposed, and address.

Name	Description	Status	Address
NS1	Connected to Distributed Energy Resources	Proposed	TBD
NS2	Connected to Distributed Energy Resources	Proposed	TBD
NS3	Town Center and Town Police	Proposed	740 W. Boston Post Rd
NS4	Mamaroneck High School	Proposed	1000 West Boston Post Rd
NS5	Sarah Neuman Nursing Facility	Proposed	845 Palmer Ave

Table 8. Mamaroneck Server Description

Table describes servers and one workstation, their status, and their addresses.

Name	Description	Status	Address
Server1	Primary EMS and SCADA server	Proposed	740 W. Boston Post Rd
Server2	Secondary EMS and SCADA server	Proposed	740 W. Boston Post Rd
Workstation	Operator/Engineer workstation	Proposed	740 W. Boston Post Rd

Figure 4. Mamaroneck One-Line Diagram

Figure provides a one-line diagram for Mamaroneck illustrating interconnections and lay-out.

REDACTED PER NDA WITH CON ED

2.6.2 Points of Interconnection and Additional Investments in Utility Infrastructure

The proposed interconnection points and equipment required for microgrid operation are listed in Table 9. The proposed point of common coupling between Con Ed's feeder and the microgrid is located at the FDR-17W32.

The microgrid will rely on automated isolation switches across the feeders to segment loads, which is required for precise microgrid control and reliability. This segmentation is critical to provide voltage and frequency control within the millisecond response intervals required for maintaining a stable microgrid and serving multiple, non-contiguous loads using distributed generators.

Table 9. List of Additional Components

Table lists all the coupling components as well as distribution devices.

Device	Quantity	Purpose/Functionality
Microgrid Control System (Siemens SICAM PAS or equivalent)	1 Primary 1 Back-up	Control system responsible for operating the microgrid sequencing and data concentration under all operating modes.
Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay)	3	Upgraded breakers/switches at distribution load feeders to enable IED interface with and control by the microgrid (Fulton Rd). Also needed at Sarah Neuman Center, preventing the microgrid from back feeding at multiple places.
Automated PME (Siemens 7SJ85 multi breaker control relay)	2	Pad Mount Enclosure with two switches and two fuses. To be updated via remote control relay capable of controlling both internal switches. (West Boston St. and Generator Location)
Automatic Transfer Switch (Siemens 7SJ85 multi breaker control relay)	4	ATS with control relay capable of current sensing and multi breaker control. Automated logic for switching to available hot feeder with one designated as the preferred. Current sensing on both feeders makes it possible to initiate emergency microgrid mode.
Generation Controls (OEM CAT, Cummins, etc.)	2	Serves as the primary resource for coordinating the paralleling and load matching of spinning generation
PV Inverter Controller (OEM Fronius, etc.)	1	Controls PV output and sends data to SCADA for forecasting
WiMax Base Station	1	Located near microgrid control cabinet. Communicates wirelessly with WiMax subscriber units for remote control and monitoring of breakers and switches. Should be installed at a high location.
WiMax Subscriber Units	4	Each subscriber unit can communicate back to the WiMax base station for SCADA monitoring and control or remote relay to relay GOOSE messaging.

All microgrid control devices and related equipment 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, a 120V alternating current (AC) power source will power an AC/DC converter to power the microgrid devices and maintain the charge of the DC battery banks. When normal AC voltage is unavailable (likely due to an issue outside of or elsewhere in Mamaroneck's distribution grid), the battery bank can provide DC power to devices for at least one week. The power supplies shall not exceed 60% power utilization from the device current draw.

2.6.3 Basic Protection Mechanism within the Microgrid Boundary

The power system protection structure 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. Existing protection schemes are based on the assumption that power flows in one direction. Bidirectional power flow during island mode will therefore 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.

2.6.4 Thermal Infrastructure

There is currently natural gas infrastructure in Mamaroneck, and as the design does not include thermal energy generation, there is no need for new steam conveyance infrastructure. At the high school, there is a 20 inch high-pressure natural gas line that will provide an adequate supply of fuel to the 1.5 MW natural gas-fired generator. At the Sarah Neuman Center, there is an 8 inch medium pressure gas connection. Size and pressure of existing gas lines contributed to the Project Team's decision to place the new natural gas generator at the high school (instead of the Sarah Neuman Center).

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. In grid-parallel mode, the microgrid will synchronize frequency and voltage magnitude with the larger grid and will have the potential to sell excess electricity to Con Ed. 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 emergency situation, the microgrid will automatically re-synchronize to the Con Ed grid (described in Section 2.7.7).

2.7.1 Microgrid Supporting Computer Hardware and Software

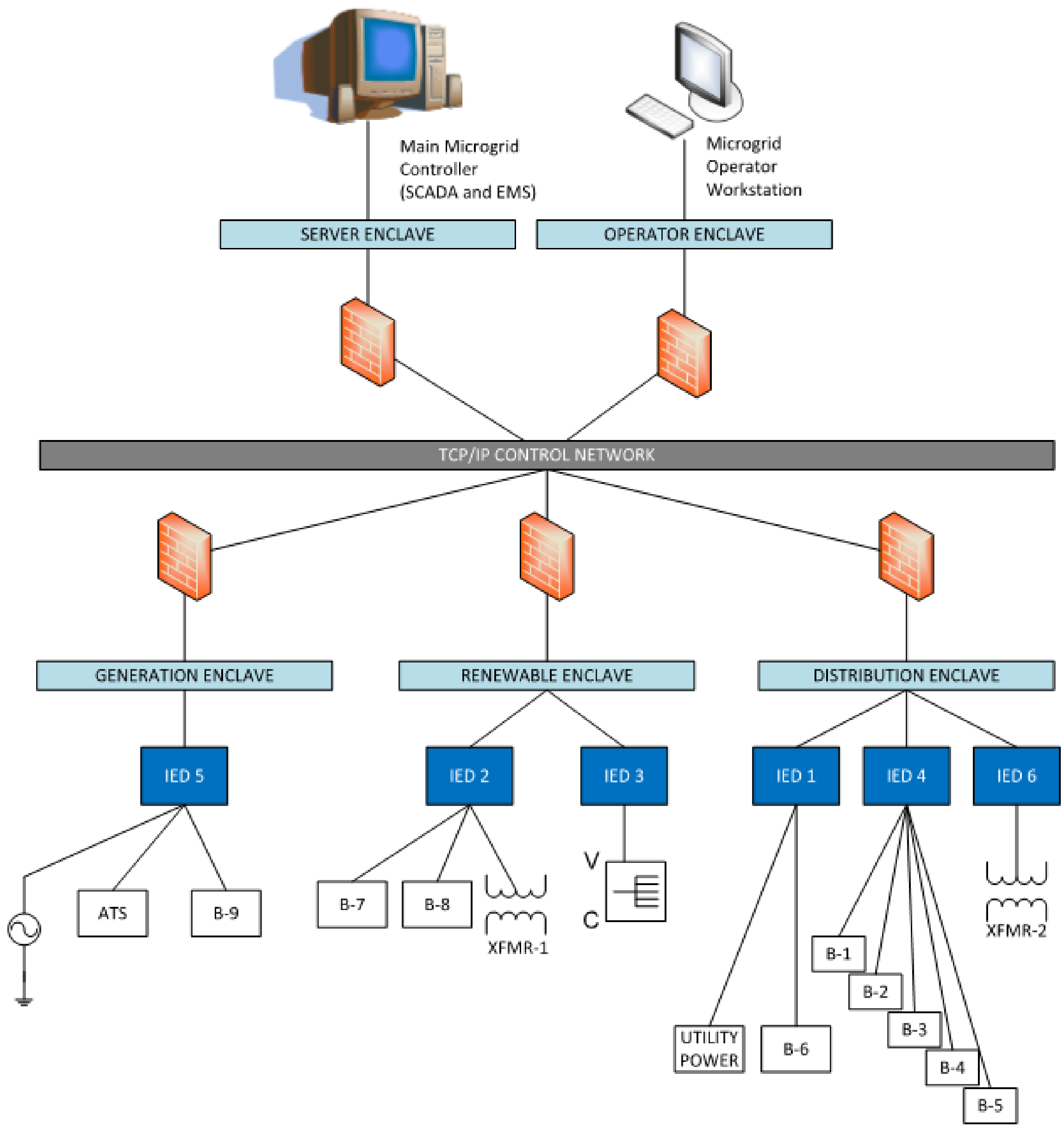
The proposed system uses a Service Oriented Architecture (SOA) software platform that will serve as the messaging and integration platform for the monitoring and control of distributed equipment. The SOA system supports almost any power device or control system from any major vendor and therefore ensures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

- SOA software platform – The SOA platform facilitates monitoring and control of included power devices and control systems.
- Redundant Array of Independent Disks (RAID) 5 servers (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 data from various devices on the network and logs information to its database.
- Applications server (one or more) – Depending on the software and hardware vendors' preference, application servers may be used for numerous purposes. Common uses for an application server include (but are not limited to) backup and recovery, antivirus, security updates, databases, a web server, or running 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 microgrid control center or a remote location. Users must have proper access rights and permissions to operate workstation computers.
- Intelligent Electronic Devices (IEDs) Distribution Switches Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay or equivalent) – The microprocessor based logic controllers in the field, also referred to as IEDs, 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. Two new IEDs will be installed at Palmer Avenue, and one will be upgraded at Fulton Road.
- Automated Pad Mounted Equipment (PME) (Siemens 7SJ85 multi breaker control relay or equivalent) – The PMEs, which include switches and fuses, are updated via remote control relay and are capable of controlling internal switches (West Boston Street and Generator Location).
- Automatic Transfer Switch (Siemens 7SJ85 multi breaker control relay or equivalent) – The ATS is capable of current sensing and multi breaker control and is equipped with remote control relay. Programmed logic will control switching to an available hot feeder, with one designated as the preferred feeder. Current sensing on both feeders facilitates the initiation of emergency island mode.

- Generation Controls (OEM CAT, Cummins, etc.) – These components are the primary resources for controlling the output of spinning generators.
- PV Inverter Controller (OEM Fronius, etc.) – This component will control PV output and send data to the MCS for forecasting.
- WiMax Base Station – This component will communicate wirelessly with WiMax subscriber units for the remote monitoring and control of breakers and switches. It will be located near the Microgrid Control Cabinet (at the Town Hall complex).
- WiMax Subscriber Units – Each subscriber unit will communicate back to the WiMax base station for monitoring and control or remote relay to relay GOOSE messaging.
- Layer 3 Gigabit Ethernet Switches – These switches connect the host servers with the logic controllers and other network attached equipment over Con Ed's WAN.

Figure 5. Diagram of a Typical Microgrid Control System Hierarchy

The following network diagram illustrates a typical microgrid control network with a generator, breakers, transformers, an ATS, IEDs (which could be actuators, Meters, Accumulators, or PLCs), a renewable energy source, and the Main Microgrid Controller with SCADA and Energy Management System (EMS) server and client workstation node.



2.7.2 Grid Parallel Mode Control

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

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

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

2.7.3 Energy Management in Grid Parallel Mode

The proposed microgrid will integrate software and hardware to ensure the highest levels of reliability and performance in all operating modes. 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 violation (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 Hertz for more than 10 minutes). The executive dashboard will calculate daily, weekly, and monthly rolling totals for all of these metrics.

When the Mamaroneck microgrid is operating in grid-connected mode, the microgrid control system will maximize the deployment of clean generation and manage local generation and curtailable loads to offset electrical demand charges.

When local generation is available, the commercial value of produced electricity will depend on a number of factors, including renewable output, duration, and load management for tariff considerations. The commercial value will be offset by the baseline costs of operation.

2.7.4 Islanded Mode Control

Island mode can be either unintentional or intentional. Unintentional islanding can be caused by an outage at the distribution system or transmission level. An outage at the distribution system level can be either within or outside the microgrid, and islanding schemes must be able to handle both cases. MCS relays will recognize low voltage, and switches that connect the microgrid to the larger Con Ed grid will open automatically. Any existing online generation will be isolated and ramped down via generation breakers. All microgrid loads and distribution switches will then be switched open via designated circuit breakers and relays to prepare for local generation startup. Using the natural gas generator’s black-start capabilities, 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 providing a stable power supply to the microgrid, the microgrid control system will bring the solar arrays on to the grid after synchronizing their voltages (amplitude and phase) and frequencies to the natural gas generator’s output. In steady state, their phases will be different, similar to grid-connected steady state operation.

The microgrid can also intentionally switch to island mode. Intentional islanding will most likely occur if:

- The Con Ed grid has an expected outage that could potentially affect transmission power to Mamaroneck substations
- The Con Ed grid needs to perform network maintenance work, thereby isolating loads at Mamaroneck area

During the intentional islanding transition, the microgrid will receive the operator’s command to prepare to enter island mode of operation. The control system will then automatically start and parallel the generation assets. Once the available power sources are synchronized with the grid and each other, the system is considered ready to implement islanded operation and will begin opening the incoming utility line breakers. Under intentional islanding, the transition into the islanding operation is seamless and closed (it does not require black start).

In island mode, the interconnecting line at FDR-17W32 will be opened to fully isolate the area controlled by the microgrid system. All available generation will be connected. Microgrid controls will maintain voltage and frequency between acceptable limits and perform load following. The microgrid control system is programmed with appropriate actions to deal with contingencies related to non-operational or non-responsive equipment at each step of the transition to islanded mode.

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

Once in islanded mode, the MCS will perform a series of operational tests to ensure the microgrid is operating as expected and is in a stable and reliable condition. Power flow, short circuit, voltage stability, and power system optimization studies will be performed using an N+1 (N components plus at least one independent backup component) contingency strategy. The N+1 strategy ensures that extra generation is always online to handle the loss of the largest spinning generator and assumes the running generator with the highest capacity could go off line unexpectedly at any time.

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
- Loss of power from the solar PV array

The MCS will optimize the Mamaroneck microgrid function by managing load and generation resources and prioritizing critical loads according to operational requirements.

The Booz Allen Team's analysis of battery storage found its cost to be prohibitively high for Mamaroneck's microgrid system. The analysis considered the potential of using storage for three purposes:

- System reliability: short term backup, often used for voltage/frequency support or to smooth intermittent renewable ramp rates
- Energy shifting: store 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: store energy from intermittent renewables for use later on to firm up the supply to 24 hours or to improve/extend island mode operation

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

2.7.6 Black Start

The proposed natural gas-fired reciprocating generator and existing diesel generator will be equipped with black start capabilities. If the Mamaroneck grid unexpectedly loses power, the microgrid controller will initiate island mode by orchestrating the predefined black start sequence. The microgrid then enters unintentional islanding mode. This mode of operation will require the generators to have a DC auxiliary support system with enough power to start the generator multiple times in case it fails to start the first time.

When utility power goes out, the microgrid controller orchestrates the black start sequence as follows:

1. PCC breaker opens
2. All active generation is disconnected
3. The main microgrid controller waits a pre-set amount of time, approximately 30 seconds (in case Con Ed power comes back)
4. The main microgrid controller disconnects the entire current load (after estimating aggregate electricity demand).
5. The microgrid generators are synchronized with each other (usually one of them provides reference voltage and frequency)
6. The main microgrid controller reconnects the microgrid loads based on the available generation and a load priority order; the microgrid is operating in islanding mode

The MCS will manage contingencies in case the breakers do not respond to trip commands and the feeder FDR-17W32 does not properly isolate from Con Ed utility power. Lower priority loads will be energized only if sufficient capacity is guaranteed. If one or more generators do not start as expected during a utility outage, the microgrid control system will be equipped with contingency algorithms to appropriately manage the situation. If possible, the control system will still isolate the microgrid, but only the most critical loads will be satisfied.

The MCS will allow operators to designate certain generators as unavailable for participation in the microgrid (e.g., if they require maintenance). The generator dispatch and load shedding algorithms must therefore be capable of accommodating a reduced available capacity. The two new pad-mounted enclosures (PMEs) will be able to shed loads and isolate generators as necessary to maintain power in islanded mode.

A primary concern is whether onsite resources can support the local loads in a stable, sustainable, and reliable fashion. The balancing of generation and load of the microgrid is a continuous operation in which analysis is performed in real time to ensure stability. The microgrid controller can leverage as much renewable generation as is available to reliably operate in conjunction with all other generating resources and load needs. The microgrid has the capability to utilize historical data and incorporate future estimates to predict peak loads and make recommendations to engineering and operations personnel. The microgrid can be designed and used to manage loads and resources for sustained cost savings.

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

2.7.7 Resynchronization to Con Ed Power

When power returns to the Con Ed grid, the microgrid controller will coordinate a safe and orderly re-connection to the larger grid. The system first waits a predefined, configurable time period to ensure that the power is permanently restored and then commences resynchronization to the Con Ed power supply. As a final check, the system operator will either receive an automated notification or directly contact Con Ed to confirm that power flow on the larger grid is on-line and stable.

While in emergency island mode, the system will constantly monitor the status of the utility feed at FDR-17W32 and determine when appropriate levels of current and voltage have been restored. When power has been restored, the control system will synchronize and parallel the microgrid generation with the utility service through the utility circuit breaker at the ATS at FDR-17W32. The 125 kW PV system will be disconnected. Before the microgrid system starts paralleling with the utility, it will balance the generation and load so as not to exceed either minimum or maximum export limits or time durations set forth in the utility interconnection agreement. Once FDR-17W32 is restored, generation breakers for the diesel generator will trip automatically. After the ATS is re-synchronized, the PV will be synchronized to the grid automatically by inverters.

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

2.8 Information Technology and Telecommunications Infrastructure (Sub Task 2.6)

The existing information technology (IT) and telecommunication infrastructure at Mamaroneck is best suited for a wireless microgrid communication system. The network will rely on several proposed network switches distributed throughout the Town. The communication system and network switches (which have local backup batteries) will communicate wirelessly with the base station located at Mamaroneck's Town Hall, which is electrically served by the microgrid in islanded mode. During the intermittent stage, or black-start sequence mode, the headend IT network equipment and base station for the IT network communications system will be powered by their backup batteries, as discussed in Section 2.7.6 and the Appendix. The microgrid hardware will require minimal additional hardware (i.e., the network switches, WiMax Base Station, WiMax subscriber units, servers, and computers required to manage a microgrid) to seamlessly integrate with the IT system.

2.8.1 Existing IT & Telecommunications Infrastructure

Mamaroneck 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 MHz industrial scientific and medical (ISM) band signal network.

2.8.2 IT Infrastructure and Microgrid Integration

Although the IT infrastructure is reliable and available for the expansion of the proposed automated microgrid system, additional microgrid hardware and software is needed. 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 SOA software that functions as the messaging and integration platform for the monitoring and control of virtually any power device or control system from any major vendor. All of these critical parts work together and serve a specific role.

2.8.3 Network Resiliency

The data transmitted throughout the proposed Mamaroneck microgrid will be encrypted, but there are several additional intrusion protection measures that can be easily implemented. One simple and inexpensive method is to disable any 65,535 TCP ports not being used to make the microgrid system work. Depending on final configuration, only a few TCP ports will need to be active. This especially depends on whether or not the available Enterprise-level or remote monitoring outside the private domain will be utilized—if this is the case, more TCP ports will need to be active.

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

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

Because the logical controllers will be located at or near loads, the distributed equipment will take the IT system to the "edge," where it is potentially more vulnerable to hackers. Sticky MAC is an inexpensive and practical program that can help prevent unauthorized access and protect the Mamaroneck network. With this program, every network attached device has a media access control (MAC) interface that is unique to it and will never change. 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.

In the event of a loss of communication with the IT system, the microgrid will still operate. The programmed logic code for the network attached controllers is stored locally in the module, giving the controllers the ability to operate as standalone computers in the event of a disruption between the IT system and microgrid. However, it is not recommended these Intelligent Electronic Devices remain separated from the network for long periods of time because this would hamper SCADA controls, historian logging, and firmware updates from upstream servers.

2.9 Microgrid Capability and Technical Design and Characterization Conclusions

After thorough examination of existing utility infrastructure and energy demand requirements, the Project Team has provided a reliable microgrid design. Control components will efficiently manage the real-time operation of the microgrid by communicating with distributed intelligent electronic devices. The proposed design is resilient to forces of nature and cyber threats, and offers full automation and expandability at every level with its SOA-based framework for ease of interoperability.

In conclusion, the project is technically feasible. However, there are still two significant barriers to project completion. The high school must find adequate space for the proposed natural gas-fired generator and solar PV array, and the express run of cable that connects the Sarah Neuman Center to the FDR-1732 and generation asset PME needs to be constructed. The Project Team expects these operational challenges to be resolved by the time of construction—the high school has considerable incentive to support the project, as connection to the microgrid guarantees a reliable supply of energy during emergency outages. The next section in this feasibility study will discuss the high capital cost associated with trenching and burying the new express cable.

Existing natural gas infrastructure will be adequate for operation of the proposed reciprocating generator, and additional investment in steam conveyance infrastructure will be unnecessary (as the design does not include CHP capability).

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

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

- The Town of Mamaroneck will own the majority share in the single SPV and that private investors will own outstanding shares. Though not a necessity, participation from the utility is advantageous because they are experienced system operators. Mamaroneck has indicated an interest in pursuing this path.
- Second, the team assumes the solar array will value electricity under a net metering agreement.
- Third, the team assumes that the natural gas-fired reciprocating generator will be able to sell electricity to Con Ed at the average local supply charge (the price Con Ed currently pays for electricity, excluding transmission, distribution, and capacity charges).
- Fourth, Con Ed will operate the microgrid as the local expert in energy distribution and the current owner and operator of the distribution infrastructure in the town. In the event that Con Ed is unwilling or unable to operate, Mamaroneck will look to a third party operator such as Con Ed Solutions.

- Lastly, this document assumes current regulatory, legal, any policy environments. The proposal falls within the existing frameworks, and in the Appendix we discuss suggested policy changes that allow for more robust microgrid structures.

The microgrid design relies on a single SPV to finance construction of the natural gas reciprocating generator, which will be the primary generation resource in the Mamaroneck microgrid. However, simply selling electricity at Con Ed's average supply price may not generate sufficient cash flow to attract investor interest in the project.

3.1 Commercial Viability – Customers (Sub Task 3.1)

The Mamaroneck microgrid will supply the local high school complex, the local town center and police station complex, and the Sarah Neuman Nursing Facility. Ownership and operation will follow a single ownership model wherein a SPV will own the proposed DERs and microgrid components/control infrastructure. Mamaroneck will likely purchase the majority stake in this SPV, with private investors and the local utility (Con Ed) purchasing the remainder of shares. Con Ed will provide helpful expertise in the day-to-day operation of the microgrid, while the Town will provide capital through the issuance long-term municipal bonds and has indicated their provisional support of a bond issuance. All of the connected facilities provide critical services to the town during emergency situations (as defined by NYSERDA). The Sarah Neuman Nursing Facility owns a diesel backup generator that will supplement the microgrid's proposed DER assets, while the other two facilities will rely entirely on the microgrid for their emergency power supply. The project will affect several groups of stakeholders in the Mamaroneck 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

All three customers to be connected to the Mamaroneck microgrid are critical facilities. The microgrid will maintain power to the town center and police station complex, the high school complex, and the Sarah Neuman Nursing Facility during island mode. The microgrid will disconnect itself from the larger grid (i.e., enter island mode) when it detects an outage on the larger Con Ed system. The microgrid will also have the technical ability to enter island mode for economic reasons (e.g., to participate in DR programs or provide cheaper electricity to customers when the spot market price is high), but it is unlikely to do so regularly.

A command from the microgrid operator will catalyze an automated sequence that will seamlessly disconnect the microgrid's DERs and loads from the larger grid. Although facilities not connected to the microgrid will not receive electricity from the microgrid's generation assets during emergency outages, they will still benefit from the availability of services at the connected facilities. Further, each of the connected facilities serves the larger community in their day-to-day operations. By providing critical services to the community, these facilities extend their reach beyond direct employees and residents in the event of emergencies. The full group of stakeholders that will benefit from the microgrid is discussed in Section 3.2.3.

Table 10 below identifies each of the direct microgrid customers and the scenarios during which they will purchase services from the microgrid.

Table 10. Microgrid Customers

Table provides a list of facilities that will be connected to the microgrid.

Property	Address	Classification	Critical Service	Back-up Generation	Normal vs Island Mode
Mamaroneck Town Center and Police Station Complex	740 West Boston Post Rd	Public	Yes	No	Both
Sarah Neuman Nursing Facility	845 Palmer Ave	Health	Yes	Yes (Diesel)	Both
Mamaroneck High School Complex	1000 West Boston Post Rd	School	Yes	No	Both

3.1.2 Benefits and Costs to Other Stakeholders

Stakeholders in the Mamaroneck microgrid extend beyond the included facilities, microgrid owners, and utility. Other stakeholders include non-connected Con Ed customers, existing generation asset owners, and residents of Mamaroneck and surrounding communities.

Our analysis of benefits and costs is broken down into the following categories:

- Supply of power during emergency outages
- Cash Flows to owners
- Upfront capital investment and land requirements

Supply of power during emergency outages: The microgrid will supply power to three critical facilities that are accessible and available to residents of the Town. These facilities can provide shelter, law enforcement, and healthcare to residents of the Town and surrounding communities in the event of a long-term grid outage. The 1.5 MW natural gas reciprocating generator and 125 kW solar array will provide load reduction for the larger Con Ed grid 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. At present, there is not a large enough steam load to support CHP implementation within the microgrid.

Cash flows: The microgrid project (primarily from associated DERs) will produce consistently positive cash flows, but not at a sufficient level to recover the project's initial capital costs absent some financial incentives. The project therefore depends on NYSERDA NY Prize Phase III funding to remain viable.

Although Mamaroneck is not considered a critical congestion point on the larger Con Ed and NYISO grids, peak load support from proposed generation assets will reduce congestion costs to NYISO, Con Ed, and their electricity customers.

Additionally, the Sarah Neuman facility stands to gain from any standby fees paid to integrate their diesel backup generation. Further, local vendors, suppliers, and labor will be heavily contracted during the planning, design, construction, and operation phases of the microgrid project.

Upfront capital investment and land requirements: The primary costs will be purchasing and installing necessary microgrid equipment and proposed generation assets. Ground-mounted PV would require a small amount of open space and would prevent any alternative use of the land. Depending on final configurations, this could be mitigated by implementing roof-mounted or carport-mounted arrays.

3.1.3 Purchasing Relationship

The Town of Mamaroneck and private investors could form a single SPV to own the proposed DERs, microgrid components and control infrastructure. Direct customers include those critical facilities listed in Table 1. The utility-purchaser relationship will largely remain the same because electricity will still flow through the same system and rates will be captured though the same billing mechanism. The SPV will sell electricity to Con Ed under a buy back agreement or other procurement model settled with Con Ed. The utility will retain a one-way electricity provision relationship, in which the customers purchase electricity from the local grid. In an islanded scenario, the facilities will be physically disconnected from the macrogrid and will acquire their electricity directly from the proposed generation assets. Associated transactions will be captured by the microgrid software and remitted to the SPV as appropriate.

The volume of electricity purchased from the NG reciprocating generator will depend on the generator's output as dictated by the microgrid controllers, system demand, and agreements between the SPV and Con Ed (acting as a utility rather than a shareholder). Electricity from the solar array will be returned to Con Ed, less on-site consumption, and will be valued at the local retail commercial rate via net metering. Depending on the Town's demand for electricity and baseline generator output, the NG reciprocating generator may also be able to sell ancillary services on the NYISO frequency capacity market. However, the minimum required capacity for participation in most NYISO ancillary service markets is 1 MW, which represents 67% of the proposed reciprocating generator's maximum output. As such, ancillary services sales are unlikely.[7] See Section 3.2.1 for a detailed description of the business model. None of the current microgrid facilities have sufficient thermal energy demand to merit the addition of CHP capability, but future microgrid expansion could reveal a larger thermal energy market.

The SPV will receive revenues from sales of electricity. Revenues will first be committed to covering operation costs and debt payments. SPV members will then receive a share of free cash flow that corresponds to their initial investment. The Project Team expects minimal participation in NYISO ancillary service markets because programs that require less than 1 MW of capacity (such as spinning and non-spinning reserves) do not provide competitive payments to participants.

[7] Ancillary service payments are not competitive with full time power sales. The overall revenues would decrease if 67% of capacity was reserved for non-electrical generating uses.

3.1.4 Solicitation and Registration

The microgrid design team will work in cooperation 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 NYPSC. Formal registration with the microgrid will be managed by programming the logic controllers to include or exclude the facility from islanded services based on their agreement with the utility.

Electricity purchases from the microgrid during normal operation will follow existing contractual and purchase relationships between the utility and the customers. Islanded operation contracts will be established during development and construction and will address the order in which islanded facilities are brought back online following an island event, the order in which facilities will be dropped to maintain N+1 (redundant) assurance, and the associated cost for participating in the microgrid. All of the aforementioned contracts are proposed and none are currently in-force. The redundant generation strategy ensures that extra generation is always online to handle the loss of the largest spinning generator and assumes the running generator with the highest capacity could unexpectedly go offline at any time.

3.1.5 Energy Commodities

Proposed generation assets include a 1.5 MW natural gas-fired reciprocating generator and a 125 kW solar PV array. Together these DERs will provide up to 1.625 MW of electricity for the microgrid and the larger community of Mamaroneck. This energy will be sold to Con Ed and will be distributed on the Con Ed system as dictated by their loads and electricity needs. If Con Ed wishes to prevent energy from flowing to the larger grid, the microgrid will be equipped with controls that have the necessary hardware and protection scheme to prevent back-feeding power into the system.

The current microgrid design does not include thermal energy output from proposed generators; however, future microgrid expansion could include facilities with thermal energy demand. If sufficient thermal energy demand develops, adding CHP capability to the proposed 1.5 MW natural gas generator could add another revenue stream for asset owners.

The viability of participating in Con Ed DR programs is discussed above in Section 2.2.22.

3.2 Commercial Viability – Value Proposition (Sub Task 3.2)

The microgrid will provide value to the Town of Mamaroneck, private investors, Con Ed, direct participants, and the larger State of New York. The 125 kW solar array and 1.5 MW natural gas generator will reduce the town's reliance on peaking assets[8] and provide stable energy resources to critical facilities in emergency situations.[9] SPV members will receive stable cash flows from

[8] NY baseload is dominated by nuclear, hydro, and natural gas. In the aggregate this is significantly lower per unit emissions than peak assets that include natural gas and coal. http://www.eia.gov/state/?sid=NY#tabs-4.

[9] The residential and industrial rates are 32% and 58% greater than the NYS averages, respectively. The area is therefore an ideal target for peak shaving.

the proposed energy generation resources and revenue from microgrid operation or connection fees for many years to come. The benefits, costs, and total value of the microgrid project are discussed in detail below.

3.2.1 Business Model

The single SPV business model will leverage the Town's low cost of capital to partially finance the project (available through the issuance of low-interest, long-term municipal bonds) and draw on Con Ed's existing electrical infrastructure and operating expertise to facilitate the microgrid's day-to-day operation. The portion of the finance contributed by non-municipal interests is expected to be acquired at market rates and not subject to the more favorable municipal bond rate. This model provides the greatest benefits to both the utility and the Town's customer base by uniting stakeholders into one commercial entity. The Town of Mamaroneck will own the majority share in the SPV, while private investors will purchase minority shares. SPV members will receive shares of free cash flow based on initial investment. The principal regulatory objection to this model is utility ownership of DERs, however Con Ed will have no majority ownership in the system if they elect to participate in ownership options at all. There is precedent in New York supporting utility ownership of distributed energy resources, particular when the generation is otherwise a qualifying facility. See the Appendix for an expanded discussion on this matter.

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

Table 11. Mamaroneck Microgrid SWOT

Table includes a discussion of the Strengths, Weaknesses, Opportunities, and Threats (SWOT) associated with the Mamaroneck microgrid project.

Strengths	Weaknesses
• Disaggregates cost burden so no single actor is responsible for the full project cost • Allows for the use of existing T&D infrastructure, thereby reducing the potential cost burden of constructing new lines and feeders (microgrid project will only require one line to connect facilities and utility line breakers to sever the connection to the larger grid) • Aligns interests of the Town (and therefore the community), Con Ed, and private investors in seeing the microgrid succeed • Leverages Con Ed expertise to facilitate load aggregation, following, voltage regulation, and other requirements of daily operation • Solar array can participate in a Con Ed Net Metering program, wherein its electricity is valued at the retail rather than wholesale rate	• Selling electricity at Con Ed's supply price will not recover all initial investment costs. The commercial feasibility of the project therefore depends on NYSERDA NY Prize Phase III funding • Long-term purchase agreements between the SPV and Con Ed are required to ensure value for the SPV's investors but may negatively impact utility credit ratings • Maximum output of proposed DERs and existing backup generator adds up to around 1.825 MW, and peak demand in the Mamaroneck grid was around 1.82 MW in 2014. The DERs will not be able to provide enough electricity for microgrid facilities if they reach their peak when the solar array is not producing at full capacity
Opportunities	**Threats**
• Model encourages teamwork between local government, private investors, and local investor owned utility (IOU); because most communities are served by IOUs, this model could serve as a template for future projects • Demonstrate the feasibility of reducing load on the larger grid and provide data to target critical congestion points on the larger grid for future projects • Model will provide data for Con Ed 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. This project could therefore prompt NYSERDA to develop a new incentive program for NG-fired DER assets	• Changes in regulatory requirements could impact the proposed business model and stakeholder goals—for example, if utilities are again permitted to own generation assets in the future, Con Ed may wish to hold competing DERs • If natural gas prices increase, it will significantly raise the microgrid's marginal cost of producing electricity, which may prompt a re-negotiation of Con Ed's purchasing price

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

- **Financial** – SPV members will seek a long-term Power Purchase Agreement, or some other form of long-term purchase agreement, with Con Ed to guarantee steady future revenue streams. However, Con Ed has a natural incentive to oppose PPAs because they represent absolute commitments of future capital and therefore drive reductions in credit ratings. Con Ed will likely negotiate for a custom procurement model based on fuel source, generator location, and generator size. 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. Con Ed's average supply price of electricity is also too low for the microgrid's owners to fully recover initial investment costs without subsidies. This could be offset if the project sells power directly to the facilities, pending further analysis on the legal viability of this type of contractual arrangement.

- **Organizational Burden** – This business model requires collaboration among groups of stakeholders that may have different motivations for participation in the microgrid project. Private investors seek profit; the Town of Mamaroneck seeks neutral returns, reduced energy prices, and improved energy resiliency; and Con Ed seeks to maintain or improve the viability of their business in Mamaroneck. However, by grouping microgrid and DER revenues and costs of operation, the business model produces a single final value stream. All SPV members are incentivized to maximize this single value stream, which makes the benefits of coordination clear (compared to a hybrid model in which multiple SPVs own different parts of the microgrid). Delineating specific roles and responsibilities in the initial contract will facilitate coordination, and estimates of intangible values (e.g., from GHG reductions or improved energy resiliency) will strengthen the project's appeal.
- **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 monopolies that could raise electricity prices without a corresponding improvement in service. Although the regulatory landscape may pose a threat, the single-SPV model itself may provide evidence that municipally owned generation assets can successfully sell electricity over a utility-owned power distribution platform.

New Technology

Minimal need for novel technology and infrastructure investments strengthen the Mamaroneck microgrid's commercial viability. However, the microgrid design includes a SCADA based control system that allows remote monitoring and control of islanding/generator output. In the future, the microgrid could be expanded to include residential, commercial, and other government and health facilities by moving switches, installing new lines, or installing Advanced Metering Infrastructure (AMI) in the Town.

Smart meter technology is advancing rapidly and will soon include the capability to remotely connect and disconnect a load based on signals received from a control system over a wireless or wired data network.

3.2.2 Replicability and Scalability

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

Technical Replicability. The proposed microgrid technology does not present a barrier to project replicability.

The primary components of the microgrid, including the proposed generation assets, switches, SCADA, and the EMS, are widely available and could be repeated in any given location. All interconnections with the Con Ed grid are industry standard. Natural gas infrastructure is an essential component of the project's replicability; without a steady natural gas supply, other communities would have to sacrifice the reliability (by relying on solar and/or wind power) or emissions efficiency (by using diesel or fuel oil) that make this project feasible.

Organizational Replicability. Because most municipalities in NYS follow a similar electricity model in which the local IOU distributes power purchased from large generation assets, the project's organizational structure is easily replicable. The combined benefits of low-cost capital from municipalities and local expertise from the utility will promote close cooperation between previously separated stakeholders and encourage adoption of this business model. 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 will offset around 30% of the solar array's capital cost, but the NG 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. This hinders the project's replicability.

Scalability. The microgrid is scalable to the limits of the electrical network architecture of surrounding power lines and the existing generation assets. The Mamaroneck microgrid does not rely on AMI meters to remotely disconnect loads that fall within the utility line breakers; therefore, any expansion will have to consider the physical realities of partitioning new power lines from the larger grid or introduce AMI remote disconnect capability to all loads between utility line breakers. Additionally, because the proposed generation assets will operate at nearly full capacity to provide enough electricity for the three proposed facilities, new generation assets are a prerequisite to expanding the microgrid in the future.

3.2.3 Benefits, Costs and Value

The microgrid will provide widely distributed benefits, both direct and indirect, to a multitude of stakeholders. The SPV will receive stable cash flows for 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 15 through 20. Moreover, except for a marginally increased price of electricity during island mode, the customers and local community (other than the Town) will not bear any of the project's costs. However, without funding from NY Prize Phase III, the cash flows generated by proposed DERs will not fully recover initial investments at Con Ed's average supply rates. This proposal involves a wide group of stakeholders—from local, non-customer residents to the State of New York—and provides value to all involved parties.

Tables 12 through 17 below provide an overview of the benefits and costs to members of the SPV, direct microgrid customers, citizens of Mamaroneck and surrounding municipalities, and the State of New York.

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

SPV shareholders will receive stable cash flows from the microgrid project for many years to come.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
SPV (Town of Mamaroneck, Private Investors, and Con Ed)	- Investors will receive annual cash flows from solar array net metering, electricity sales from the NG reciprocating generator, and microgrid connection or participation fees - NY Sun incentive recovers 30% of solar array's cost in the project's first year - NY Prize Phase III funding could recover up to $5 MM of initial project costs	- Initial capital outlay will be significant because the SPV must purchase and install generation assets, microgrid control equipment, and distributed microgrid equipment - Forecasted installed capital costs for the solar array and NG reciprocating engine are ~$220,000 and ~$2 MM, respectively - Ongoing maintenance of DERs and microgrid equipment - Financing costs associated with initial capital outlay will persist for many years	- By leveraging the Town of Mamaroneck's relatively low cost of capital and Con Ed's existing infrastructure and domain expertise, a single SPV will successfully finance and maintain the Mamaroneck microgrid - Improved energy resiliency and reduced reliance on high-emission peaking assets

Table 13. Benefits, Costs, and Value Proposition to Consolidated Edison, Inc.

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Con Ed (as local utility)	- As proposed, the utility will continue to sell electricity to direct customers - Con Ed will avoid complete loss of revenues in emergency outage situations - 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	- Con Ed will purchase electricity from the NG reciprocating generator at a price consistent with its existing electricity supply costs	- The utility can serve as a market connector while only paying a fraction of normal construction and operation costs - Improved grid resiliency by integrating local generation assets with local distribution networks - Con Ed will have a new supply of electricity valued at their average supply charge but will marginally reduce their T&D costs in the immediate area

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Town of Mamaroneck (as local government)	- Town hall complex 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 - Meet NY REV goals by encouraging DER construction and improving energy resiliency - In the future, the municipal government facilities could transition to co-generated steam for thermal energy - Further integration as a smart community - 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 keep the lights on during outages, allowing the Town of Mamaroneck 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 solar PV arrays and a natural gas fired reciprocating generator will offset high-emission peaking assets during peak demand events - Provides a community education resource

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Connected Facilities (High School, Town Hall Complex, Sarah Neuman Nursing Facility)	- Resilient and redundant energy supply to operations - Access to a local market for distributed energy generation makes investments in small DERs more attractive to connected facilities	- Slightly higher electricity prices during island mode - Connection and operation fees as part of connecting to the microgrid (to support microgrid equipment financing and maintenance)	- Replacing fuel oil or natural gas boilers with steam heat could provide significant savings to future facilities (if CHP is added to NG recip. generator) - Maintain operations during emergency outages and provide valuable critical services to the Mamaroneck 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 16. Benefits, Costs, and Value Proposition to the Larger Community

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Community at Large	- Access to a wide range of critical and vital 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 Mamaroneck will likely need to install AMI meters in hundreds of facilities for this to be feasible

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
New York State	- 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	- By reducing peak load on the larger grid, every microgrid's DER assets will reduce the state's use peaking assets—thus reducing GHG emissions and achieving NY State goals - 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 DERs in their own communities - Success of SPV model aligns with REV goals—this project provides a successful example of investor-owned generation assets selling electricity over a utility-owned power distribution platform

3.2.4 Demonstration of State Policy

This section discusses the Mamaroneck microgrid as proposed. For an expanded discussion of policy changes required to support more robust microgrids and a strong path forward with REV, please refer to the Appendix.

The proposed microgrid coordinates with REV by providing a utility-maintained power distribution platform for locally owned DER assets. The single SPV model has the potential to be extremely successful by leveraging a lower weighted average cost of capital as well as local utility expertise and is highly replicable. This project could therefore serve as a valuable example of an innovative, profitable relationship between IOUs, municipalities, and private investors.

By reducing electricity consumption through Con Ed energy efficiency programs and increasing generator output during peak demand events, the Mamaroneck microgrid could participate in lucrative Con Ed DR programs. However, the natural gas generator will rarely have sufficient standby generating capacity available to participate in DR programs. As discussed in the Appendix and Section 2.2.22, disconnecting the entire microgrid during peak events is unlikely to qualify for Con Ed DR programs.

By coordinating the microgrid as the local distributed system platform (DSP), the Mamaroneck microgrid will act as a distributed resource and will provide local stabilization through injections and withdrawals of power from the grid. 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.

The Town of Mamaroneck has already made significant progress towards achieving the NY REV goals. The Town commissioned a Sustainability Collaborative committee to advise on environmental issues and is developing a Sustainability Plan to improve resiliency, sustainability, and the quality of life in the Town. This initiative prompted energy efficiency upgrades for the ice rink, town center, fire headquarters, and Town streetlights. Additionally, the Solarize Westchester campaign (which included the towns of Mamaroneck and Larchmont) provided planning and design support to help local residents and businesses install solar arrays at a lower cost. Mamaroneck is a NYS Climate Smart Community and participates in numerous state solar and energy programs including K-Solar, PACE financing (pending), Municipal Buyers Solar Group, a State unified solar permit, energy audits for municipal facilities, and Community Choice Aggregation (pending).

The microgrid in Mamaroneck provides a local market for excess electricity generated by distributed renewable generation assets, greatly improves resiliency and reliability of local energy supply in extreme weather situations, and encourages citizens within the community to invest in local energy generation and distribution. Mamaroneck’s microgrid and DER assets will immediately reduce the town’s reliance on high-emission peaking assets during peak demand events and provide a platform for expanding the town’s clean DER capability in the future.

The microgrid also encourages participation in programs associated with the Renewable Portfolio Standard (RPS) policy. Incentive programs include NY Sun, NYSERDA On-Site Wind, NYSERDA Fuel Cells, and NYSERDA Renewable Heat. The microgrid will provide a tangible local example of incentive value as well as the long-term savings customers can realize by investing in renewable generation and energy efficiency. For example, the NY Sun Program will recover around 30% of capital costs associated with the proposed solar array. The NY Sun Program applies to commercial arrays that are under 200 kW and residential arrays that are under 25 kW and is worth 30% of the system’s installed cost. The Mamaroneck microgrid provides an excellent platform for energy produced by these solar arrays and, along with the NY Sun Program, will encourage residential, commercial, and municipal investment in solar energy for many years to come.

3.3 Commercial Viability – Project Team (Sub Task 3.3)

The Project Team includes Con Ed, the Town of Mamaroneck government, Booz Allen Hamilton, Siemens AG, Power Analytics, Pace Law School, and Sustainable Westchester. It may expand to include financiers as the project develops. Details on the Project Team can be found in this section.

3.3.1 Stakeholder Engagement

The Project Team has been engaged in constant communication with local stakeholders from the outset. Booz Allen and its Town partners have also communicated with each of the proposed facilities to gauge electric and steam demand and discuss other aspects of the project development.

3.3.2 Project Team

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

Table 18. Project Team

Table provides background on Booz Allen Hamilton, Siemens AG, Power Analytics, and Con Ed.

<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>Consolidated Edison, Inc.</th><th>Headquarters: New York, NY</th><th>Annual Revenue: $13 B</th><th>Employees: 14,500</th></tr>
<tr><td colspan="4">History and Product Portfolio: For more than 180 years, Consolidated Edison has served the world’s most dynamic and demanding marketplace—metropolitan New York. Con Ed provides electric service to approximately 3.3 million customers and gas service to approximately 1.1 million customers in New York City and Westchester County. The company also provides steam service in certain parts of Manhattan. Con Ed receives yearly operating revenues of approximately $13 BN and owns assets totaling approximately $44 BN.</td></tr>
</table>

Table 19. Project Team Roles and Responsibilities

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

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
Consolidated Edison, Inc.	Con Ed could purchase a minority share in the owning SPV. Regardless of ownership involvement, the utility's expertise will be essential in planning microgrid construction. The utility also has the option to participate in long-term operations and maintenance of the system.	Con Ed will provide a share of the initial capital outlay that corresponds to its ownership share of the SPV.	Con Ed will provide the necessary domain expertise to operate and maintain the microgrid. If they serve as the operator, this will include responsibility for switching to island mode and regulating voltage and frequency across the microgrid's loads in both grid-connected and island mode.
Town of Mamaroneck	The Town will purchase the majority share in the proposed SPV. It will serve as the main conduit to representatives of the critical and vital facilities and other interests in the town. This effort is spearheaded by the Town Supervisor, who is responsible for local outreach.	As the liaison, the Town will coordinate with all local and state parties as needed. The Town will also provide a share of the capital outlay that corresponds to its ownership of the SPV.	As the liaison, the Town will coordinate with all local, regional, and state parties as required. The Town will also provide a share of necessary services and capital to maintain the microgrid that correspond with its ownership share of the SPV.
Booz Allen	BAH is responsible for the delivery of the Feasibility Study and its component parts. This includes serving as the central clearinghouse of data, design, and proposal development as well as the key POC for NYSERDA on this task.	BAH will serve in an advisory and organizational role, working in a similar prime contractor capacity to provide overall design, costing, and construction management services.	BAH would serve in an outside, advisory capacity upon completion of the microgrid and during its operation.
Siemens	Siemens is the engineering and technology partner of this project. They will develop the technical design and system configuration in concert with BAH engineers and the Power Analytics team.	Siemens may have primary responsibility for the shovel-in-the-ground construction and installation of hardware and generation assets.	Ensuring proper functioning and maintenance of the microgrid technology components throughout.
Power Analytics	Power Analytics is the partner for energy software solutions. The PA team, in conjunction with Siemens and Booz Allen, is responsible for the design of the SCADA and system software components and controls.	Power Analytics may lead the installation of control and energy management software following hardware installation and in concert with Siemens.	Provide IT systems support; may play an active role in system management through the EnergyNet software platform.

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
Suppliers	There are no suppliers required during this development phase; however, project partners and suppliers Siemens and Power Analytics are closely involved in feasibility and design portions of the project. BAH is in touch with several additional suppliers of hardware and software including Duke Energy, ConEd Solutions, Enel Green Power, Anbaric Transmission, Bloom, and Energize.	Siemens or another engineering and technology firm will be the hardware supplier, including switches and other physical controls. Power Analytics or another software company will be the EMS and SCADA provider, responsible for software and server components.	The installer of the hardware and software will continue to provide maintenance and advisory services as required to ensure proper and efficient functioning of their components. The software provider will work in cooperation with Con Ed to assess the best approach to daily operations of the software system.
Financiers/Investors	Outside finance advisors will be leveraged to assist the potential Mamaroneck bond offering and creation of the Special Purpose Vehicle. The SPV will be created during the project development phase. Investors will provide capital for majority stakes in generation assets and minority stakes in microgrid components/control infrastructure. Investors may include any of the entities mentioned in the row above.	Outside financial advisors will be retained to assist the bond offering and drawdown of funds. Debt and equity investors will supply the cash required to complete the construction and installation of generation assets and microgrid controls.	Outside financial advisors will be retained to assist with any issues in bond repayment that may arise. Generation asset owners will realize revenues from the sale of electricity and thermal resources. Microgrid system owners will realize revenues from the microgrid tariff, and Con Ed may realize T&D depending on final financial agreements.
Legal/Regulatory Advisors	Legal and regulatory advice is housed both within Booz Allen and through project partner Pace Climate and Energy Center. 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, Con Ed, and any investor counsel required.	Legal and regulatory will be the responsibility of the Town, the utility, and any investors in the Special Purpose Vehicle.

3.3.3 Financial Strength

The principal shareholders in the microgrid project are the Town of Mamaroneck, Con Ed, and private investors that purchase a minority share in the SPV.

Moody's Investor Service rates Consolidated Edison, Inc., at an A3 credit rating. According to the Moody's rating scale, "Obligations rated [A] are judged to be upper-medium grade and are subject to low credit risk." This rating reflects the supportiveness of the US regulatory environment. Although Con Ed's credit ratings fell in 2009, Con Ed's regulatory environment has since become more benign. There are few serious competitors in Con Ed's space (metropolitan New York), and Con Ed has invested in several innovative initiatives that should improve reliability of service and relationships with customers.

Consolidated Edison, Inc. is a subsidiary of Consolidated Edison Company of New York, Inc., which also operates Orange & Rockland Utilities, Inc. Con Ed owns assets worth approximately $44 BN and receives annual revenues of approximately $13 BN. Revenues have been consistent for years, and Con Edison recently posted an increase in dividends per share for FY 2014.

Moody's gives the Town of Mamaroneck's $9 MM GO bonds a long-term credit rating of Aa1, its second highest ranking. An obligation rated as "Aa" indicates that "obligations…are judged to be of high quality and are subject to very low credit risk". This indicates that the Town will qualify for relatively low interest rates should it choose to finance the microgrid project with debt.

The Town of Mamaroneck will be responsible for evaluating potential private investors to ensure they can provide committed capital throughout the project's lifecycle.

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 Supervisory Control and Data Acquisition (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 microgrid design includes the installation of knife switches, automated switches, and gang-operated air breakers. The automated switches are necessary for automatic grid segmentation, which is required for precise microgrid control and reliability of power supply and were selected for this reason. Construction of a power line across the football field will be necessary to connect the Sarah Neuman "loop" to the high school and town center complex.

A solar PV array and a natural gas-fired reciprocating generator were chosen as generator technologies to reduce GHG emissions and enhance the reliability of the power supply. The NG 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. It will also reduce the need for diesel generation in emergency outage situations and will be capable of providing ancillary services to the macrogrid, potentially creating another revenue stream for the microgrid. The Project Team performed extensive analyses on the viability of CHP/cogeneration in Mamaroneck, but thermal demand is limited to

Sarah Neuman's hot water supply. Installation of any significant CHP unit is cost prohibitive until facilities with more thermal demand connect to the microgrid.

The solar PV unit will provide a renewable component to the microgrid generation mix and is a more appropriate addition than an expanded NG unit. It will provide emission-free electricity during daylight hours and move Mamaroneck 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 Mamaroneck that it does elsewhere in the northeastern United States: variable weather conditions and long periods of darkness in the winter. If these generators go offline for maintenance or due to an unexpected emergency, the diesel backup generator at Sarah Neuman will come online and provide 200 kW of power to microgrid-connected facilities.

The Town possesses an IT and telecommunication infrastructure that is best suited for a wireless microgrid communication system. The present network architecture is conducive to the addition of an automated microgrid, but it will rely on several existing network switches. Mamaroneck uses its existing fiber optic backbone ring and Ethernet switches for internet and LAN activities—this existing hardware will support the necessary communication between microgrid control devices. The wireless components of the proposed system will use a TCP/IP Ethernet-enabled component that controls each of the uniquely addressed modules. Data transmitted over the proposed microgrid's network will be encrypted, and the Project Team has proposed several additional cyber security measures that will ensure data safety.

Load and generation balance are ensured by several microgrid design elements and will remain true in both normal operation and islanded operation. In normal operation, available capacity from the NG reciprocating generator and the solar PV will be primarily committed to meeting facility demand. If connected facilities unexpectedly require more electricity than the DERs can provide, the microgrid's system controllers will automatically support the inflow of electricity from the Con Ed grid. The controllers will also recognize when the solar PV and NG unit are out-producing microgrid demand and will provide for the flow of power back into the Con Ed grid. The microgrid will rarely have to import power from the Con Ed grid because peak afternoon electricity demand will often follow peak solar potential. Flow to the Con Ed grid will be based on agreements on interconnection power volumes and quality, and in the event that export to the Con Ed grid is prohibited, the microgrid controllers will instruct the generation assets to appropriately follow microgrid load. The NG unit's ability to provide reactive power and frequency response services will provide the microgrid with the flexibility to follow uncertain demand patterns. In the case of an unplanned transition to islanded mode, the SCADA and microgrid controllers will disconnect loads from the system and disconnect the microgrid from the Con Ed grid via the installed switching components. A controlled reconnection of the critical and vital facilities will commence based on available generation, and it may expand beyond those facilities if there is sufficient capacity based on the N+1 framework.

The Mamaroneck 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 GW of solar PV installed in 2015 in the United States. In July of 2015, New York State produced a net 6,000 gigawatt hours (GWh) of natural gas-fired electricity.[10] The switch components are all industry standard and are widely used in utilities worldwide, and the IEDs, 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.[11]

3.4.2 Operation

All members of the SPV will contribute funds to operate and maintain the grid, but as the team's Subject Matter Expert, Con Ed will oversee most of the logistics associated with day-to-day operation. The microgrid is a classic shared-value entity; the utility, Town, and customers will benefit financially, and the continued success of the grid requires support and collaboration from all three.

The microgrid will be operated by the SPV, but Con Ed will have the most influence on decisions regarding the grid that are not automatic elevations to the State or PSC. Decisions as to the proper level of generation from local assets, load following, N+1 assurance, and other similar issues will be addressed automatically in real time by the logic controllers and microgrid control system. 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 Con Ed grid will be automatically governed by the microgrid controllers

All members of the SPV will be technically responsible for the continued and successful operation of the component pieces of the grid, including software, switches, servers, generation, and AMI meters, but they will have ongoing assistance from Siemens, Power Analytics, and others. 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.

Con Ed will purchase electricity from the DER asset owners and distribute this energy to the microgrid-connected facilities (and larger grid if there is excess power). The facilities will continue to be billed for electricity via the regular Con Ed billing mechanism and cycle. Con Ed's revenue will be sufficient to cover the supply cost of electricity (from the DERs) as well as Con Ed-imposed delivery and capacity charges. Additional fees may be imposed upon microgrid participants as a percentage of their tariff. However, given the extremely limited amount of time forecasted in island operation and the commensurately limited time that the customers will need to rely on the microgrid, this will be no more than 1% of the connection tariff.

Project financing will require monthly or annual payments on the bonds issued to support construction. The Town will likely bear some financing costs as they repay issued bonds.

[10] EIA: http://www.eia.gov/state/?sid=NY#tabs-4.
[11] Siemens case studies; available from http://w3.usa.siemens.com/smartgrid/us/en/microgrid/pages/microgrids.aspx.

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 and limited ability to participate in DR and ancillary services markets further hinders financial returns. Assuming the SPV will sell electricity to Con Ed at their current supply charge, the microgrid will produce positive net income from year to year. However, after discounting future cash flows, annual net income does not provide sufficient revenue for a stand-alone positive net present value (NPV) business case.[12] The Mamaroneck microgrid qualifies for relatively few of the available state and federal incentives for DER assets—the NY Sun program will offset 30% of the capital cost of the solar array, but this only amounts to around 1-2% of total project cost.[13] As such, it must rely on direct project-generated revenues and NY Prize Phase III funding for its commercial viability.

3.4.4 Permitting

The Mamaroneck microgrid may require certain permits and permissions depending on the ultimate design choices. Distributed energy resource assets will require zoning variances because they will be placed on high school land. The SPV may need to apply for a revocable consent in order to lay the new express line between the HS and Sarah Neuman. Mamaroneck is not in any EPA criteria pollutant nonattainment zones; however, the reciprocating generator will require air quality permits pursuant to the Clean Air Act.

3.5 Financial Viability (Sub Task 3.5)

The distributed energy resource assets included in the microgrid design will produce revenue streams from electricity sales to Con Ed (or directly to the facilities if operation as a QF is allowed as discussed in the Appendix). These assets will require significant initial capital outlay as well as annual operation and maintenance (O&M) costs. The microgrid project qualifies for the NY Sun incentive, which will partially offset the initial investment costs. Municipal revenue bonds issued by the Town of Mamaroneck will provide the majority of the required capital outlay for the Town's share in the SPV. Private investors will use a mix of debt and equity to finance their shares. This section will discuss the revenues, costs, and financing options associated with the microgrid project in more detail.

3.5.1 Revenue, Cost, and Profitability

The microgrid has a number of savings and revenue streams, as outlined in Table 20. The revenues will sum to approximately $820,000 per year, while fuel, operation, and maintenance will cost around $725,000 per year. Although yearly cash flows should be positive, they do not recover initial investment costs after discounting (see outline of the capital and operating costs in

[12] The Booz Allen Team forecasts the break-even sales price of electricity to be ~$0.125/kWh if proposed distribution lines are installed underground, and ~$0.096/kWh if they are installed overhead. This forecast does not include NY Prize Phase III funding or revenue from participation in Con Ed DR programs. NY Prize Phase III funding would recover capital costs and upgrade the project to a financially net-positive investment.

[13] Depending on whether proposed distribution lines are installed overhead or underground.

Table 21). The commercial viability of the Mamaroneck microgrid project therefore depends heavily on Phase III NY Prize funding.

Table 20. 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 1.5 MW natural gas-fired reciprocating generator during grid connected mode[14]	Revenue	~$800,000/yr	Variable
Electricity sales from 125 kW solar PV array (Net Metered) during G-C mode	Savings	~$20,000/yr	Variable
Electricity sales to customers during islanded operation	Revenue	~$500/yr	Variable
Microgrid participation tariff	Revenue	1%	Variable
Total Yearly Revenue and Savings		**~$820,000/yr**	Variable

Table 21. Capital and Operating Costs

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

Description of Costs	CapEx or OpEx	Relative Magnitude	Fixed or Variable
1.5 MW NG Recip. Generator	Capital	$2,000,000	Fixed
125 kW Solar PV array	Capital	$200,000	Fixed
Distributed Equipment	Capital	$150,000	Fixed
Microgrid Control System	Capital	$350,000	Fixed
IT costs (wireless and cables)	Capital	$40,000	Fixed
Proposed Power Line (connecting HS/Town Center to SN Nursing)[15]	Capital	$300,000 (overhead) $2.3 MM (underground)	Fixed
Total CapEx		**$3 MM** (overhead line)	Fixed
NG Generator Fuel	Operating	$575,000/yr	Variable
NG Generator Maintenance	Operating	~$150,000/yr	Variable
Solar PV Maintenance	Operating	~$2,500/yr	Variable
Total OpEx		**$725,000/yr**	Variable

The proposed microgrid will qualify for only one existing incentive program: the NY Sun program. The program will 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 MM but will not exceed total capital costs) and capacity payments for participation in Con Ed DR programs. The

[14] The Booz Allen Team calculated Con Ed's supply charge for electricity to be approximately $0.0729/kWh in Zone I (Dunwoodie). This is the assumed price for grid-connected sales from the NG recip. generator.

[15] Costs for running line overhead and underground are both given. Approximately 4,300 feet of new line will be required. Overhead line cost: $60/ft (Con Ed estimate). Underground line cost: $540/ft (Con Ed estimate).

Mamaroneck microgrid will be able to enter island mode to participate in DR programs, but doing so removes its generation capacity as well as load off the larger grid. Because its generators will operate nearly continuously throughout the year, entering island mode may not qualify as an eligible change from baseline operation. In other words, the microgrid's generation assets will provide a constant level of load reduction, but it is unlikely that consistent load reduction will qualify for Con Ed's DR programs. See Table 22 for details on the available incentive programs.

Table 22. 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	~$5,000,000	Required
NY Sun	~$65,000	Required

3.5.2 Financing Structure

The development phase is characterized by the negotiation and execution of the construction financing and debt structure and agreements with any equity partners. Awards from Phase II of the NY Prize Community Microgrid Competition will 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. The Town of Mamaroneck will provide 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 PSC, and firm financing for the construction of the project (described below).

The SPV will leverage Phase III funding from NYSERDA to complete the construction phase and will supplement with capital from municipal bonds and private investors as necessary. 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 $3 or $5 million, depending on whether new distribution lines are installed overhead or underground), and municipal or private funding will represent the balance of the financing.

The Town of Mamaroneck is willing to issue municipal bonds to finance their share in the SPV. Issues to be addressed during the negotiations related to the bond terms are:

1) Limits of the basic security
2) Flow-of-funds structure
3) Rate (or user-charge) covenant

4) Priority of revenue claims
5) Additional-bonds tests
6) Other relevant covenants

The bonds will be backed by the Town's share of revenues generated during the operation of the microgrid. The project will generate sufficient cash flows to satisfy the obligations due to bondholders without contribution from Con Ed DR programs. Financing obligations will depend on the Town's share in the SPV, amount of NYSERDA NY Prize funding received, and magnitude of future operation and maintenance costs. Specific market conditions at the time of issuance will determine interest rate and repayment schedule.

We assume that the Town will grant the physical space for the siting of generation at no cost as it is the primary beneficiary of the proposed microgrid. The SPV will maintain ownership over all generation assets and microgrid infrastructure. Single ownership will promote coordination in the pre-construction phase and remove the need for a construction financing structure such as lease-leaseback.

3.6 Legal Viability (Sub Task 3.6)

Like any infrastructure project that involves development of public and private land, the Mamaroneck 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 Ownership and Access

Legal considerations will include access limitations, franchising, zoning, and permitting.

The microgrid will be owned and operated by the single SPV, with the Town of Mamaroneck owning a majority share. Microgrid equipment, including generation, will be installed on town or facility-owned land. Property rights and access limitations will not be a concern for components installed on town-owned land, but the SPV should make sure to address these issues for components (such as DERs) that are installed on facility-owned land. The data network that supports the microgrid logic units and controllers is owned by the Town of Mamaroneck—access to this network will not represent a significant barrier to project completion.

3.6.2 Regulatory Considerations

State and Utility Regulation

An important legal question under this ownership model is whether the microgrid qualifies as an electric distribution company under Public Service Law and, if so, what level of regulation it will fall under at the Public Service Commission (PSC). New models of regulatory treatment (currently under discussion in REV proceedings) may also apply if adopted.

Under existing law, the microgrid will be treated as an electric corporation under Public Service Law unless it is deemed a qualifying facility under the terms of PSL §§ 2(2-d) or otherwise qualifies for lightened regulation. The spectrum of regulation that the PSC may exercise over an electric corporation includes:

- General supervision (investigating the manufacture, distribution, and transmission of electricity; ordering improvements; and performing audits)
- Rates
- Safe and adequate service
- Billing process; financial, record-keeping, and accounting requirements
- Corporate finance and structure

However, the microgrid is unlikely to be exempt from much of this regulation because does not appear to meet the criteria for a "qualifying facility" under the terms of PSL §2. The Mamaroneck microgrid will include a 125 kW solar PV array, will not generate more than 80 MW of power, and will connect facilities located near generators (the solar array and NG-fired reciprocating generator will both be constructed at the high school). The inclusion of non-CHP, natural gas-fired generation should remove the Mamaroneck microgrid from Qualifying Facility consideration. Please see the Appendix for an expanded discussion.

Local Regulation

All entities that require the use of public ways (i.e., for transmission or distribution facilities) must be granted permission by the presiding municipal authority in the form of a franchise or some lesser consent, depending on the scope of the usage. The cities, towns, and villages of New York have specific statutory authority to grant franchises. As provided by N.Y. Vil. Law § 4-412, every Village Board of Trustees is empowered to grant franchises or rights to use the streets, waters, waterfront, public ways, and public places of the city.[16] "Use" encompasses occupying public rights-of-way and operation of the provider's built infrastructure to provide the public service.[17]

In the Town of Mamaroneck, the process for granting a franchise for electric distribution wires is governed by the Town's Telecommunications Franchising and Licensing Provisions, which applies to franchises for telecommunications as well as "other right of way authorizations." The Telecom Code provides two avenues for securing rights to lay wire: a franchise or a revocable consent. A revocable consent can be granted only up to 2,500 feet of wire; the necessary line from the Sarah Neuman Nursing Facility to the high school is expected to be shorter, so this should remain an option for the microgrid. A franchise is not inhibited by these length limits but is subject to more expansive terms and conditions.

The processes for the Town's review of application for a franchise or a revocable consent are the same. The Town Manager and Town Attorney review the application, and then the Board of Trustees is given broad latitude to make additional investigations or take any steps it deems

[16] N.Y. Vil. Law § 4-412.
[17] See, e.g., "Contract of April 7, 1887 between Hess et al. Commissioners & Consolidated Telegraph & Electrical Subway Co." (Con Tel and Electrical Subway Company Agreements 1886-1891.pdf).

appropriate to act on the application. After it has completed its review, the Board has the right to grant or deny the application.

Because the high school is an R-20 district, electric power generation is normally not permitted on-site. There are no special provisions or permits for electrical generation in the Town of Mamaroneck, so microgrid owners will likely need to seek a variance from the Zoning Board of Appeals. Given the close coordination with the Town in the development of the Feasibility Study, the Project Team does not foresee this as an insurmountable condition.

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 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 Mamaroneck 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

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

New York state has enacted amendments to Environmental Conservation Law Articles 19 (Air Pollution Control) and 70 (Uniform Procedures) as well as DEC amended regulations 6NYCRR Parts, per the 1990 Amendments to the Clean Air Act. With this demonstration of authority, DEC received delegation of the Title V operating permit program from the US Environmental Protection Agency (EPA). Title V Permits are required for all facilities with air emissions greater than major stationary source thresholds. New York's air pollution control permitting program 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 Mamaroneck microgrid project will include three critical facilities from the Town of Mamaroneck (the high school, town center complex, and Sarah Neuman Nursing Facility) and will be owned by a single Special Purpose Vehicle. The Town will purchase the majority share in the SPV, with other private investors purchasing minority shares. This ownership structure will give the project owners access to low cost capital (through the Town's ability to issue municipal revenue bonds) and significant domain expertise (through Con Ed's knowledge and experience with electricity distribution in the area). The single SPV structure also coordinates shareholder interests by tying return on investment to one single shared value stream.

The proposed microgrid's commercial feasibility depends on NY Prize Phase III funding. Its design includes two new DERs to be located at the high school: a 1.5 MW natural gas fired reciprocating generator and a 125 kW solar photovoltaic array. The SPV will provide the capital required to purchase and install these generators and will receive revenues from electricity sales to Con Ed throughout the generators' lifespan. All members of the SPV will contribute funds to the daily operation and maintenance of the microgrid components and DERs, and Con Ed, or a third party operator, will leverage its local expertise to keep the microgrid components and control infrastructure running smoothly. The Project Team forecasts yearly revenues of approximately $820,000 and yearly operation and maintenance costs of approximately $725,000 (including fuel for natural gas and diesel generators). The project will produce positive annual net incomes, but it will also require subsidies to fully recover initial investment costs (after discounting future cash flows).

These estimates and value propositions are predicated on several assumptions. First, private investors must have sufficient interest in the microgrid project to provide supplementary capital for the initial construction costs. Similarly, the system operator will be involved to facilitate the smooth day-to-day operation of the microgrid and its control infrastructure. The solar array will sell electricity at the average local commercial retail rate through a Net Metering Agreement with Con Ed. Finally, the project concept proposes Con Ed will purchase electricity generated by the reciprocating generator at the utility's average supply price of electricity.

In addition to revenues from electricity sales, the microgrid will provide indirect financial and non-financial benefits to Mamaroneck citizens, SPV shareholders, Con Ed, and larger Westchester community. Improved energy resiliency 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 maintain electric service to more facilities in Mamaroneck and reveal a larger market for thermal energy—adding CHP capability to the proposed 1.5 MW reciprocating generator would improve its efficiency and add a new revenue stream to the SPV's portfolio.

Permitting and regulatory challenges should be reasonably straightforward, although the SPV and high school will need to seek a zoning variance in order to install the reciprocating generator and solar PV array on the high school's land and, potentially, revocable consent or other approval to lay new lines. The primary regulatory consideration will be the Clean Air Act permitting of the new reciprocating generator.

The next section of this Feasibility Study will provide an in-depth cost and benefit analysis for the project and an overall summation and lessons learned in the development of the study.

4. Cost Benefit Analysis

The Cost Benefit Analysis section 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 distributed energy resources*, 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 Mamaroneck microgrid will include three facilities from multiple rate classes and economic sectors. NYSERDA designates three primary rate classes based on type of facility and annual electricity consumption: residential, small commercial (less than 50 MWh per year), and large commercial (greater than 50 MWh per year). See Table26 for basic statistics on each facility's energy usage. Two of the proposed microgrid facilities belong to the large commercial rate class and the other is a small commercial facility. The two large commercial facilities account for approximately 93% of the microgrid's annual electricity demand, with the small commercial facility, the Mamaroneck Town Center and Police Station, makes up the remaining 7% of annual electricity demand.

Public sector facilities such as Mamaroneck High School account for around 55% of annual microgrid electricity usage, which was around 275.5 MWh in 2014. Health facilities such as the

Sarah Neuman Nursing Facility account for around 45% of annual microgrid electricity usage, which was around 228.6 MWh in 2014.The average electricity demand in 2014 was approximately 0.69 MW and aggregate peak demand never exceeded 1.81 MW.

During a major power outage, the generation assets included in the microgrid design will be capable of meeting 100% of average aggregate facility energy usage, but may approach their generation limits if the two large facilities simultaneously reach peak energy use. In these situations, the backup diesel generator may need to come online to supply additional electricity. Some of the facilities do not operate at full capacity for 24 hours a day. Facilities, such as Mamaroneck High School, will only operate 12 hours per day during grid-connected mode. Some critical facilities that normally operate less than 24 hours per day may need to operate continuously in emergency island-mode situations. For example, the high school complex normally requires electricity for lighting, electrical appliances, and heating/cooling during the daytime hours, but could serve as a community shelter in emergencies. This will extend its electricity usage window from 12 hours per day to 24 hours per day. For information on each facility's average daily operation during a major power outage, see Table 23.

Table 23. Facility and Customer Detail Benefit[18]

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 CON ED

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

4.2 Characterization of Distributed Energy Resource (Sub Task 4.2)

The microgrid design incorporates distributed energy resources, including one existing diesel generator, a proposed natural gas-fired generator, and a proposed solar PV array. The proposed natural gas unit and solar PV array will produce an average of 1.29 MW of electricity throughout the year[19] (including projected capacity factors), and the existing diesel generator at the Sarah Neuman Nursing Facility will provide up to 200 kW of backup generation capacity during emergencies.

The natural gas generator has a nameplate capacity of 1.5 MW and will operate nearly continuously. Assuming a capacity factor of 85%, the natural gas unit will produce approximately 11,170 megawatt hours (MWh) of electricity over the course of the year. If a major power outage occurs, the natural gas unit will produce an approximately 36 MWh of electricity per day, which would provide over 100% of the microgrid's average daily demand. The natural gas units use around nine Mcf (1000 ft^3) of natural gas per MWh generated, which amounts to a fuel cost of around $53/MWh to operate.[20]

Limited by weather conditions and the availability of sunlight, the 0.125 MW solar PV array is expected to produce around 153 MWh per year (assuming a capacity factor of 14%).[21] Because many outages are caused by severe weather events, solar panels cannot be relied upon to provide energy during emergency outages without supplementary battery storage. However, on average the solar array will produce 0.75 MWh of electricity per day, which represents 2.5% of average daily electricity demand from microgrid-connected facilities. Maintenance costs for the solar array will be around $2,500 per year,[22] which means the marginal cost of producing solar electricity will be about 34/MWh.[23]

The existing diesel generator at the Sarah Neuman Nursing Facility will be used only in islanded situations when the microgrid requires a black start or when the proposed natural gas generator and solar array are not producing sufficient electricity to meet aggregate demand. The generator at the Sarah Neuman Nursing Facility has a nameplate capacity of 0.2 MW. This 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 forecasts around 2.67 hours of larger grid outage based on Con Ed's Customer Average Interruption Duration Index from 2013,[24] and therefore predicts that annual output from backup diesel generators will be

[19] Natural Gas 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).
[20] Price of natural gas: $5.74 per Mcf (average CHGE supply price from 2013-2015).
[21] Solar array capacity factor: 14% (NREL PV Watts Calculator).
[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: $300,000 (Siemens).
Variable cost: 20 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).
[24] Grid outage data from DPS 2013 Electric Reliability Performance Report (Con Ed average CAIDI)

insignificant. The 0.2 MW generator requires around 16.4 gallons of fuel per hour of operation.[25] In the event of a major power outage, the generator could produce up to 4.8 MWh/day—however, assuming that the natural gas generator and solar will require backup power during only 20% of emergency outage hours,[26] this figure drops to .96 MWh/day. See Table 24 for a detailed list of all proposed and existing distributed energy resources in Mamaroneck.

[25] Backup Diesel Generator fuel consumption rate – 16.4 gallons/hour (Cummins Power Generation – DSHAC model, 200 kW)

[26] The Booz Allen team forecasts a 20% level of operation from the backup generator based on historical loads and expected generator output. In 2014, the average load in Mamaroneck was 0.69 MW. The natural gas generator can provide a maximum of 1.5 MW of generation. Load is expected to exceed the natural gas generator's maximum output for approximately 20% 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 24. Distributed Energy Resources

Table lists DERs incorporated in the microgrid, including their energy/fuel source, nameplate capacity, estimated average annual production under normal operating conditions, average daily production in the event of a major power outage, and fuel consumption per MWh generated (for fuel-based DERs). "Normal operating conditions" assumes approximately .534 effective hours of operation per year for the diesel 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 - Proposed Solar Panel	Land behind 1000 West Boston Post Rd	Solar	0.125	153.3	0.42	1.0[27]	N/A	N/A
DER2 - Proposed Natural Gas Unit	Land behind 1000 West Boston Post Rd	Natural Gas	1.5	11,169	30.60	36	9.26 Mcf	9.5 MMBTUs
DER3 – Backup Diesel Generator	Sarah Neuman Nursing Facility	Diesel	0.2	.101	.96	4.8	82 Gallons	11.38 MMBTUs

[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 microgrid. The existing diesel generator will also be available to offset peak load in cases of extreme demand. See Table 25 for the maximum generation capacities of the proposed and existing DERs.

The proposed solar array will be at its most productive on the most irradiated days of year when peak demand events are common, thus providing peak load support when it is most needed. It will provide around 0.0175 MW of load support on average over the course of a year. However, because its generation depends on weather conditions and time of day, the solar array is not a reliable source of peak load support.

Table 25. Distributed Energy Resource Peak Load Support

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

Distributed Energy Resource Name	Location	Available Capacity (MW)	Does distributed energy resource currently provide peak load support?
DER2 - Proposed Natural Gas Unit	Land behind 1000 West Boston Post Rd	Maximum of 1.5	No[28]
DER1 - Proposed Solar Panel	Land behind 1000 West Boston Post Rd	Maximum of 0.125	No

4.3.2 Demand Response

See Section 2.2.22 for a detailed overview of the project's ability to participate in DR programs.

4.3.3 Deferral of Transmission/Distribution Requirements

Con Ed has a robust grid in Mamaroneck's region with little congestion, therefore the 1.3 MW of average local generation produced by the DERs will only marginally 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,[29] they can only transmit a limited amount of power. As demand for electricity in Mamaroneck 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

[28] As the facility is running constantly it will be providing peak reduction by changing the baseload demand profile but does not function in the same manner as a peaker-plant.

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

certain cases (e.g., if the assets are placed in remote locations and thus expensive to connect to the local grid). Although Mamaroneck has ample capacity within the town, approximately 4,300 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

See Section 2.2.28 for a detailed overview of the project's ability to participate in ancillary service markets.

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 Mamaroneck grid. For example, the natural gas generator will provide frequency regulation as a by-product of its operation. The Mamaroneck 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 steam off-takers within a technically feasible distance of the generation site, the Project Team decided to propose a natural gas generator instead of a combine head and power (CHP) unit. Therefore, there is no proposed CHP unit for the Mamaroneck microgrid.

4.3.6 Environmental Regulation for Emission

The microgrid's generation assets will drive a net 2,020 $MTCO_2e$ (metric tons CO_2 equivalent) increase in GHG emissions in Mamaroneck as compared to the New York State energy asset mix. The proposed generation assets will produce around 11,320 MWh of electricity per year. The natural gas unit and backup diesel generators will emit approximately 6,130 $MTCO_2e$ per year, [30] while the solar arrays will emit none. The current New York State energy asset mix would emit approximately 4,110 $MTCO_2e$ to produce the same amount of electricity.[31] The microgrid's generation assets will therefore result in a net increase in emissions by 2,020 $MTCO_2e$.

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

[30] Natural Gas Generator Emissions Rate: 0.55 MTCO2e/MWh (EPA, http://www3.epa.gov/chp/documents/faq.pdf) Natural Gas 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).

[31] 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).

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 JJJJJ—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 diesel gas generator is already permitted and therefore will not incur any significant emissions costs.

Table 26 catalogs the CO_2, SO_2, NO_x, and Particulate Matter (PM) emissions rates for the natural gas and diesel generators.

Table 26. Emission Rates

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

Distributed Energy Resource Name	Location	Emissions Type	Emissions Per MWh (Metric Tons/MWh)
DER2 - Proposed Natural Gas Unit	Land behind 1000 West Boston Post Rd	CO_2	0.553
		SO_2	0.0000067[32]
		NO_x	0.00055[33]
DER3 – Backup Diesel Generator	Sarah Neuman Nursing Facility	CO_2	0.7196[34]
		SO_2	0.1911[35]
		NO_x	2.9074[36]
		PM	0.2046[37]

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.
- IEDs to interface with the 44 kilovolt (kV) utility breaker at the substation as well as the smaller 8.3 kV distribution feeders.

[32] Emissions calculator, EPA.
[33] EPA, http://www3.epa.gov/chp/documents/faq.pdf.
[34] Diesel Generator Emissions rate: 0.72 $MTCO_2e$/MWh (assuming 161 lb CO_2e per MMBTU; EIA, http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11).
[35] Michigan Department of Environmental Quality; Environmental Science and Services Division. "Potential to Emit, Diesel Fired Generator Calculation Worksheet"
[36] Ibid.
[37] Ibid.

- Automated breakers installed throughout Mamaroneck 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 $667,000 and $20,000 for the IT infrastructure. The cost of overhead powerline installation will be $235,000 or $2.3 million if the powerlines are installed underground.[38]The Project Team estimates the 0.125 MW solar PV array and 1.5 MW natural gas unit carry an installed cost of $300,000 and $1.95 million, respectively.[39] This brings the total installed capital cost to approximately $3.17 million if the powerlines are installed overhead, not including interconnection fees and site surveys. If the powerlines are installed underground the total installed capital cost will be $5.24 million. Additionally the estimated capital cost does not account for any financial incentives or tax credits that may lower the overall cost of the microgrid. See Tables 27 and 28 below for estimated installed costs for each microgrid component.

The Project Team estimates nearly every piece of microgrid equipment has a useful lifespan of 20 years. The only component with a shorter lifespan will be the microgrid control system (Siemens SICAM PAS or equivalent), which will be replaced by more advanced software after 7-8 years.

Table 27 details capital cost of the distributed equipment, which includes the microgrid control system and centralized generation controls that will allow the operator and electronic controllers to manage the entire microgrid.

[38] Cost estimate provided by Travers Dennis - Con Ed.
[39] Natural Gas Generator Capital Cost: $1,300/kW, pro-rated from Siemens 1.5 MW Natural Gas estimate.
Solar PV Capital Cost: $2,400/kw, pro-rated from Siemens 2 MW Solar PV estimate.

Table 27. Distributed Equipment Capital Cost

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

Distributed Equipment Capital Costs				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
Microgrid Control System	1 Primary	$50,000 (total)	7 - 8	Control system responsible for operating the microgrid sequencing and data concentration under all operating modes.
(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)	3	$15,000	20	Upgraded breakers/switches at distribution load feeders to enable IED interface with and control by the microgrid (Fulton Rd). Also needed at Sarah Neuman Center, preventing the microgrid from back feeding at multiple places.
Automated PME (Siemens 7SJ85 multi breaker control relay)	2	$40,000	20	Pad Mount Enclosure with two switches and two fuses. To be updated via remote control relay capable of controlling both internal switches. (West Boston St. and Generator Location)
Automatic Transfer Switch (Siemens 7SJ85 multi breaker control relay)	1	$90,000	20	ATS with control relay capable of current sensing and multi breaker control. Automated logic for switching to available hot feeder with one designated as the preferred. Current sensing on both feeders makes it possible to initiate emergency microgrid mode.
Generation Controls (OEM CAT, Cummins, etc.)	2	$4,000	20	Serves as the primary resource for coordinating the paralleling and load matching of spinning generation
PV Inverter Controller (OEM Fronius, etc.)	1	$2,000	20	Controls PV output and sends data to SCADA for forecasting
Network Switches	2	$50,000	20	Located at IEDs and controllers for network connection, allowing remote monitoring and control.

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.
WiMax Subscriber Units	5	$10,000	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	-	$23,000	-	The configuration and testing of the WiMax hardware
Installation Costs	-	$75,000	-	Installation of capital components in the microgrid

Table 28. Capital Cost of Proposed Generation Units

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

Proposed Generation Units				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
0.125 MW PV System	1	$300,000	30	Generation of electricity
1.5 MW Natural Gas Unit	1	$1,950,000	20	Generation of electricity

The microgrid IT infrastructure will also require Cat-5e Ethernet and 1000 Base-F two strand fiber optic 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,[40] for distances under 100 meters. For greater distances the design calls for fiber optic cables using LC connectors at a cost of $7.60 per cable.[41] The total installation cost of cabling is approximately $5.65 per foot for Cat-5e cables and approximately $4.65 per foot for fiber optic cables.[42] The Project Team will use the existing cabling infrastructure to install the communications cables, thereby avoiding the high costs of trenching the proposed lines.

40 Commercially available RJ-45 connectors, $0.30 per connector.
41 Commercially available LC connectors, $3.80 per connector.
42 Installation costs for Cat5e: $5.45/ft. Installation costs for fiber optic: $4.40/ft (Siemens).
Component cost for Cat5e: $0.14/ft (commercially available). Component cost for fiber optic: $0.24/ft (commercially available).

Additionally, the microgrid's IT infrastructure will need five new network switches at a cost of $750 each. The estimated total cost for the microgrid IT infrastructure is around $20,000.[43]

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 $235,000 for an overhead installation and $2.3 million for an underground installation.[44]

4.4.2 Initial Planning and Design Cost

The initial planning and design of the microgrid includes four preparation activities and total to approximately $1 million.

1. The first set of activities are the design considerations and simulation analysis which will cost approximately $750,000 to complete.
2. The second activity focuses on the financial aspects of the project including project valuation and investment planning which will cost approximately $100,000.
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 $75,000.
4. The fourth activity focuses on the development of contractual relationships with key partners will cost approximately $75,000.

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

[43] The Project Team estimated ~2,230 feet of Cat5e and ~575 feet of fiber optic will be necessary.

[44] The Project Team has determined that approximately 4,300 feet of new line is required at the cost of $60/ft for overheard installation and $540/ft for underground installation according to Travers Dennis at Con Ed.

Table 29. Initial Planning and Design Cost

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

Initial Planning and Design Costs ($)[45]	What cost components are included in this figure?
$750,000	Design considerations and simulation analysis
$100,000	Project valuation and investment planning
$75,000	Assessment of regulatory, legal, and financial viability
$75,000	Development of contractual relationships
$1,000,000	**Total Planning and Design Costs**

4.4.3 Operations and Maintenance Cost

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

Annual service for the natural gas unit will cost around $156,400.[46] The microgrid owner will also incur $2,500/year in total costs for annual fixed system service agreements for the solar PV array and backup diesel generators.[47]

The DERs 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 $5.74/Mcf, which translates to an average fuel cost of $0.0515/kWh for the natural gas unit.

The diesel fuel usage of the backup diesel generators is difficult to predict because they will be used only during some emergency outage situations. The average price of diesel fuel in New York State from 2013-2015 was $3.91 per gallon, which translates to an average fuel cost of approximately $0.28/kWh (assuming an output of 14.1 kWh/gallon). The high price of diesel fuel, along with increased GHG emissions, discourages extended use of the diesel generators.

The solar PV array 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.[48]

---

[45] Estimates developed by Booz Allen Project Team and independent consultant.
[46] Natural Gas O&M: $0.014/kWh. (Siemens).
[47] $5,000 for solar PV array ($20/kW per year) and $4.60/kW per year for backup diesel generators (Electric Power Research Institute, "Costs of Utility Distributed Generators, 1-10 MW").
[48] NREL (projects $0/kWh variable maintenance costs): http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.

Annual service for all non-DER microgrid components will cost approximately $70,000 per year.[49] Table 30 outlines all fixed operations and maintenance (O&M) costs associated with normal operation of the DERs.

Table 30. Fixed Operating and Maintenance Cost

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

Fixed O&M Costs ($/year)	Cost Components
~ $2,500	Solar PV System Service Agreement – Annual costs of maintenance and servicing of unit
~ $156,400 including both fixed and variable costs	Natural Gas Unit Service Agreement and Employee Costs – Annual costs of maintenance and servicing of unit and labor cost of running natural gas unit
~$1,000	Diesel 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

4.4.4 Distributed Energy Resource Replenishing Fuel Time

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

At full operation, the 0.2 MW diesel generator at the Sarah Neuman Nursing Facility will require 16.4 gallons of diesel fuel per hour at full load. The Sarah Neuman Nursing Facility has a 400 gallon diesel storage tank installed, so at a 100% level of output this generator can operate for 24 hours without replenishing its fuel supply. Cutting output to 50% increases the maximum operation time to 48 hours.

The solar PV array does not require fuel for operation, but its output depends on weather and time of day. Table 31 shows the fuel consumption and operating times for all of the microgrid DERs.

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

Table 31. Maximum Fuel Operating Time for Distributed Energy Resource

Table displays the potential maximum operating times in Islanded Mode for each DER. The corresponding fuel consumption for each DER is also detailed.

Distributed Energy Resource	Location	Energy Source	Maximum Operating Time in Islanded Mode without Replenishing Fuel (hours)	Fuel Consumption During this Period	
				Quantity	Unit
DER1 - Proposed Solar Panel	Land behind 1000 West Boston Post Rd	Sun Light	N/A	N/A	Gallon
DER2 - Proposed Natural Gas Unit	Land behind 1000 West Boston Post Rd	Natural Gas	N/A	N/A	MMBtu
DER3 – Backup Diesel Generator	Sarah Neuman Nursing Facility	Diesel	24	400	Gallon

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 generators in the event of an extended power outage. The natural gas generator will be the most reliable and productive of the DERs, providing a maximum of 1.5 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 up to 36 MWh per day, using approximately 333 Mcf (342 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 and could provide up to 0.125 MW of load support to the Mamaroneck microgrid. Table 32 shows all of the costs associated with operating the DERs during a power outage, including fuel and variable O&M costs.

The backup diesel generators will only come online when the natural gas unit and solar array do not provide sufficient power to the islanded microgrid. Because the natural gas generator can produce 1.5 MW of power at full capacity and the microgrid's loads had an average power demand of 0.69 MW during 2014, the natural gas generator and solar array should be capable of satisfying the microgrid's power demand in most situations. The diesel generators will only be necessary for about 20% of total outage time. At 20% operation the 0.2 MW diesel generator would produce an average of 0.96 MWh per day. The backup generator will require around 80 gallons of fuel per day at this level of generation. One-time startup costs or daily non-fuel maintenance costs for either of the diesel generators are not anticipated.

Table 32. 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		
Land behind 1000 West Boston Post Rd	DER1 - Proposed Solar Panel	Sun Light	0.125	14%[50]	.42[51]	N/A	N/A	N/A	$6.50[52]
Land behind 1000 West Boston Post Rd	DER2 - Proposed Natural Gas Unit	Natural Gas	1.5	100%	3.6	333	Mcf	N/A	$2,050
Sarah Neuman Nursing Facility	DER3 – Backup Diesel Generator	Diesel	.2	100%	4.8	384	Gallons	N/A	$1,500[53]

[50] Capacity factor includes weather and daylight.
[51] 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.
[52] = Yearly O&M/365.
[53] = Daily fuel cost during an outage (gallons/day) + (Yearly O&M/365).

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 32. Please refer to Table 32 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 Mamaroneck (such as the Town Center and Police Department). Others, like the Mamaroneck High School, serve a smaller population for most of the year, but provide critical services to the entire population during emergency situations. For estimates of the population served by each critical facility, see Table 33.

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. receiving a 911 call or local water sanitizing operations). Based on the portfolio of services that each facility provides and the electricity dependency of each service, Table 33 provides an estimate of how effectively each facility can perform its normal services without electricity.

Table 33. 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[54]	
		When Backup Power is Available	When Backup Power is Not Available
Mamaroneck Town Center and Police Station	~ 29,000[55]	0%	50% - 75%
Sarah Neuman Nursing Facility	~ 400[56]	0%	> 75%
Mamaroneck High School	~ 1,500[57]	0%	> 75%

4.7 Industrial Economics Benefit-Cost Analysis Report

4.7.1 Project Overview

As part of NYSERDA's NY Prize community microgrid competition, the Town of Mamaroneck has proposed development of a microgrid that would serve three facilities located in close proximity to one another along Palmer Avenue and West Boston Post Road:

- The Sarah Neuman Center, a post-acute care facility, nursing home and outpatient treatment center with approximately 365 residents.[58]
- The Mamaroneck Town Center and Police Station.
- Mamaroneck High School, a public secondary school with a total enrollment of approximately 1,500 students.[59]

The microgrid would be powered by two new distributed energy resources – a 1.5 MW natural gas unit and a 125 kW photovoltaic array – both of which would be installed on a nearby parcel of land off West Boston Post Road. In addition, the microgrid would incorporate a 200 kW backup diesel generator currently installed at the Sarah Neuman Center. The town anticipates that the natural gas unit and photovoltaic system would produce electricity for the grid during periods of normal operation. In contrast, the diesel generator would produce power only if necessary during an outage, when the microgrid would operate in islanded mode. The system as

[54] 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).
[55] Number of citizens in Mamaroneck.
[56] Combine number of patients and staff affiliated with the Sarah Neuman Nursing Facility.
[57] Number of students and teachers affiliated with Mamaroneck High School.
[58] http://jewishhome.org/news-and-events/news/sarah-neuman-center-opens-first-small-house/.
[59] Proposed Budget of the Board of Education, Mamaroneck Public Schools, 2015-2016 School Year. Accessed December 17, 2015 at http://www.mamkschools.org/download.axd?file=830970d4-1ae8-4101-9678-32c7065865a1&dnldType=Resource.

designed would have sufficient generating capacity to meet average demand for electricity from the three 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.[60] It also calculates an annualized estimate of costs and benefits based on the anticipated engineering lifespan of the system's equipment. Once a project's cumulative benefits and costs have been adjusted to present values, the model calculates both the project's net benefits and the

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

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.[61]

4.7.3 Results

Table 34 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 5.1 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

Table 34. BCA Results (Assuming 7 Percent Discount Rate)

Economic Measure	Assumed Average Duration of Major Power Outages	
	Scenario 1: 0 Days/Year	Scenario 2: 5.1 Days/Year
Net Benefits - Present Value	-$6,340,000	$41,600
Benefit-Cost Ratio	0.7	1.0
Internal Rate of Return	NA	8.0%

[61] 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.

Scenario 1

Figure 6 and Table 35 present the detailed results of the Scenario 1 analysis.

Figure 6. Present Value Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

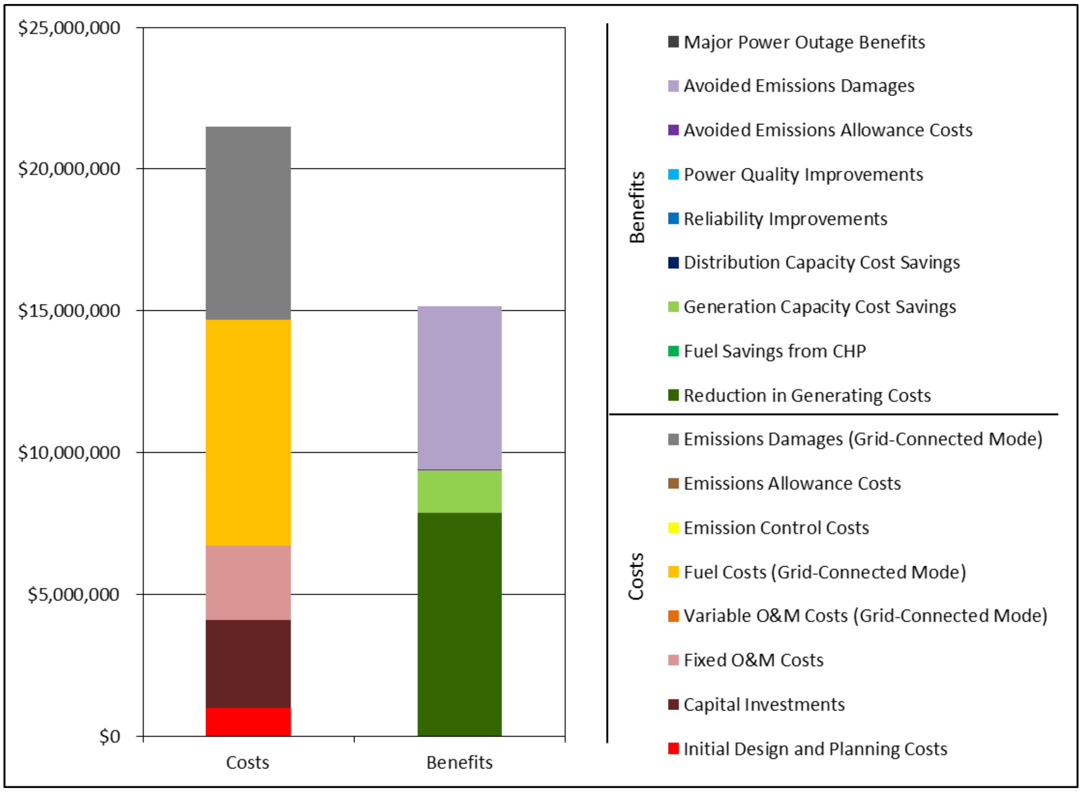


Table 35. Detailed BCA Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value Over 20 Years (2014$)	Annualized Value (2014$)
Costs		
Initial Design and Planning	$1,000,000	$88,200
Capital Investments	$3,110,000	$265,000
Fixed O&M	$2,610,000	$230,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$7,960,000	$702,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$6,830,000	$446,000
Total Costs	**$21,500,000**	
Benefits		
Reduction in Generating Costs	$7,890,000	$696,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$1,480,000	$130,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$22,900	$2,030
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$3,880	$342
Avoided Emissions Damages	$5,770,000	$376,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$15,200,000**	
Net Benefits	**-$6,340,000**	
Benefit/Cost Ratio	**0.7**	
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 $1.0 million. The present value of the project's capital costs is estimated at approximately $3.1 million, including costs associated with installing a microgrid control system; equipment for the substations that will be used to manage the microgrid; the IT infrastructure (communication cabling) for the microgrid; the new 1.5 MW natural gas unit and 125 kW photovoltaic array; and the power lines needed to distribute the electricity the microgrid would generate. Operation and maintenance of the entire system would be provided under fixed price service contracts, at an estimated annual cost of approximately $230,000. The present value of these O&M costs over a 20-year operating period is approximately $2.6 million.

Variable Costs

The most significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the system's primary generator. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the Project Team and projections of fuel costs from New York's State Energy Plan (SEP), adjusted to reflect recent market prices.[62] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $8.0 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 new natural gas generator are estimated at approximately $446,000 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 $6.8 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 Mamaroneck'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 $7.9 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. The reduction in demand for electricity from bulk energy suppliers would also reduce emissions of CO_2 and particulate matter from these sources, and produce a shift in demand for SO_2 and NO_x, emissions allowances. The present value of these benefits is approximately $5.8 million.[63]

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.[64] 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 1.2925 MW per year (the team estimates no impact on distribution capacity).

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

[63] 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.

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

Based on this figure, the BCA estimates the present value of the project's generating capacity benefits to be approximately $1.5 million over a 20-year operating period.

The Project Team has indicated that the proposed microgrid would be designed to provide ancillary services, in the form of black start support, to the 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 $2,000 per year, with a present value of $22,900 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:[65]

- System Average Interruption Frequency Index – 0.11 events per year.
- Customer Average Interruption Duration Index – 181.2 minutes.[66]

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.[67] 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.

[65] www.icecalculator.com.
[66] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for Consolidated Edison.
[67] 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 0.7; i.e., the estimate of project benefits is approximately 70 percent that of project costs. Accordingly, the analysis moves to Scenario 2, taking into account the potential benefits of a microgrid in mitigating the impact of major power outages.

Scenario 2

Benefits in the Event of a Major Power Outage

As previously noted, the estimate of reliability benefits presented in Scenario 1 does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.[68,69]

As noted above, the Town of Mamaroneck's microgrid project would serve three facilities: the Sarah Neuman Center; the Mamaroneck Town Center and Police Station; and Mamaroneck High School. The project's consultants indicate that at present, only the Sarah Neuman Center is equipped with a backup generator; the level of service this unit can support is approximately half the ordinary level of service at the center. Should this unit fail, the Center could maintain operations by bringing in a portable diesel generator with sufficient power to maintain all services. The operation of this unit would cost approximately $7,800 per day. Similarly, the town center/police station and the high school could maintain service by bringing in portable generators, at a cost of approximately $1,500 per day for the former and $9,500 per day for the latter. In the absence of backup power – i.e., if the backup generator failed and no replacement was available – all three facilities would experience at least a 75 percent loss in service capabilities.

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:

---

[68] 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.

[69] 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.

- The Sarah Neuman Center would rely on its existing backup generator, experiencing a 50 percent loss in service capabilities while the generator operates. If the backup generator fails, the facility would experience a total loss of service.
- The Mamaroneck Town Center and Police Station would rely on a portable generator, experiencing no loss in service capabilities while this unit is in operation. If the portable generator fails, the police department would experience a 100 percent loss in service effectiveness.
- Mamaroneck High School would also rely on a portable generator, experiencing no loss in service while this unit is in operation. If the portable generator fails, the school would experience a total loss of service.
- In all three cases, the supply of fuel necessary to operate the backup generator 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 analysis calculates the impact of a loss in the town's police services using standard FEMA values for the costs of crime, the baseline incidence of crime per capita, and the impact of changes in service effectiveness on crime rates. The impact of a loss in service at other facilities is based on the following value of service estimates:

- For the Sarah Neuman Center, a value of approximately $138,000 per day. This figure is based on an estimate of the facility's capacity (365 beds) and state data on the average rate for nursing home care in the area ($377/patient/day).[70]
- For Mamaroneck High School, a value of approximately $107,000 per day. This figure is based on the school district's budget for the current school year, scaled to an average daily value and prorated by the percentage of the district's student body who attend the high school.[71]

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for the three facilities is approximately $111,000 per day.

[70] https://www.health.ny.gov/facilities/nursing/estimated_average_rates.htm. Note that this value is at best a rough approximation of the social welfare loss attributable to a loss of power at a facility of this type, as it does not account for potential impacts on the health and well-being of residents or for changes in the cost of caring for residents during an extended outage.

[71] Proposed Budget of the Board of Education, Mamaroneck Public Schools, 2015-2016 School Year (http://www.mamkschools.org/download.axd?file=830970d4-1ae8-4101-9678-32c7065865a1&dnldType=Resource). Note that this value is at best a rough approximation of the social welfare loss attributable to a loss of power at the school, as it does not account for the potential to reschedule lost school days when power is restored; the impact of disruptions in schedule on the productivity of teachers, school administrators, or children's caregivers; the effect of an extended outage on the cost of operating and maintaining the school; and other factors that would more accurately characterize the impact of a loss of service during an extended outage.

Summary

Figure 7 and Table 36 present the results of the BCA for Scenario 2. The results indicate that the benefits of the proposed project would equal or exceed its costs if the project enabled the facilities it would serve to avoid an average of 5.1 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

Figure 7. Present Value Results, Scenario 2

(Major Power Outages Averaging 5.1 Days/Year; 7 Percent Discount Rate)

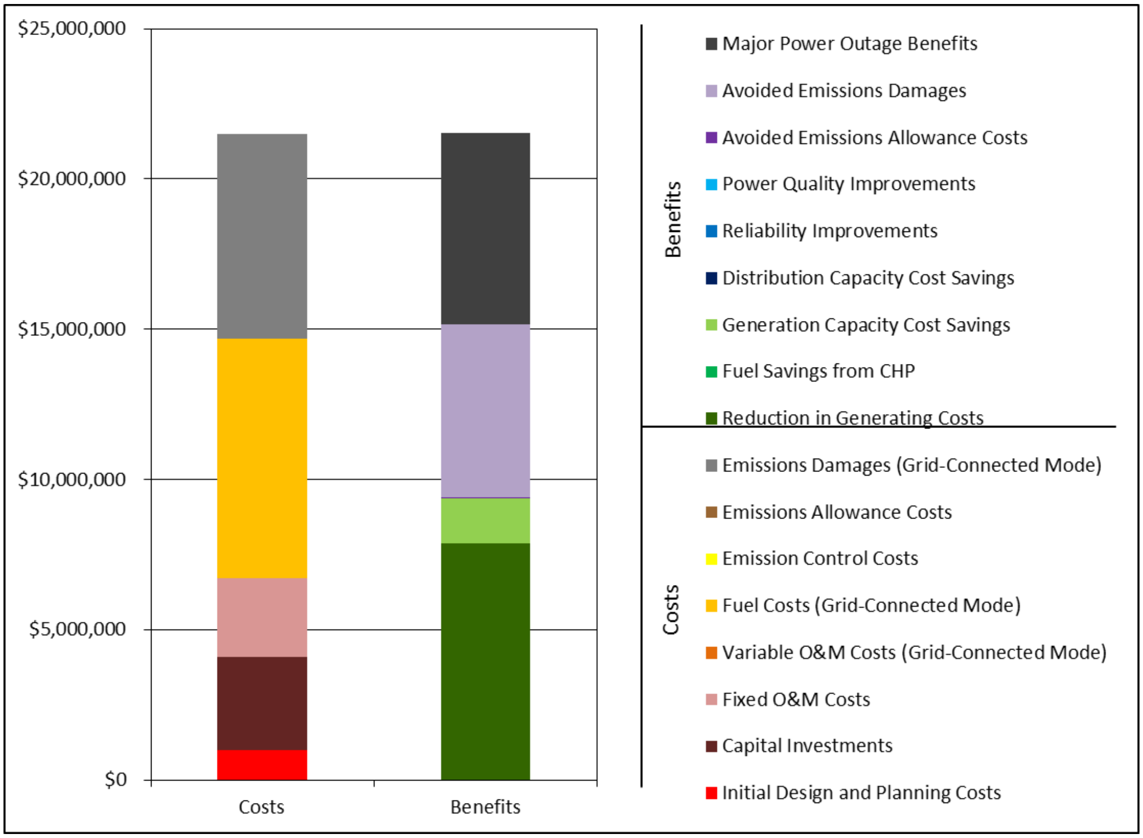


Table 36. Detailed BCA Results, Scenario 2

(Major Power Outages Averaging 5.1 Days/Year; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value Over 20 Years (2014$)	Annualized Value (2014$)
Costs		
Initial Design and Planning	$1,000,000	$88,200
Capital Investments	$3,110,000	$265,000
Fixed O&M	$2,610,000	$230,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$7,960,000	$702,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$6,830,000	$446,000
Total Costs	**$21,500,000**	
Benefits		
Reduction in Generating Costs	$7,890,000	$696,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$1,480,000	$130,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$22,900	$2,030
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$3,880	$342
Avoided Emissions Damages	$5,770,000	$376,000
Major Power Outage Benefits	$6,390,000	$566,000
Total Benefits	**$21,500,000**	
Net Benefits	**$41,600**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**8.0%**	

The Project Team assumed an electricity sales price of $0.073 per kWh in Mamaroneck. This is the supply cost for Con Ed, the average amount spent by Con Ed 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 Con Ed grid. In Mamaroneck, the Dunwoodie LBMP is $39.16 per MWh[72], or $0.039 per kWh, a more than 45% reduction in price from the supply cost. The benefits allowed for capacity cost reductions do not bring the electricity prices to parity. This has a predictable influence on the economics of the projects and is the driving force behind the divergent cost benefit analyses developed by the Project Team and by IEc. The Project Team is unaware of any community microgrid business model or generation set that is financially self-sufficient at the LBMP.

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

5. Summary and Conclusion

The Booz Allen team has assembled the necessary data for an independent cost-benefit analysis of the Mamaroneck microgrid. The Project Team assembled real cost and load data wherever possible and filled knowledge gaps with research-based assumptions.

The Mamaroneck microgrid includes three facilities comprised of two rate classes (defined by NYSERDA) and two economic sectors (including public and health). The most of the facilities fall under NYSERDA's large commercial rate class, meaning they are non-residential facilities with an annual electricity demand that is greater than 50 MWh per year. Public sector facilities such as Mamaroneck High School account for around 55% of annual microgrid electricity usage, which was around 275.5 MWh in 2014. Health facilities such as the Sarah Neuman Nursing Facility account for around 45% of annual microgrid electricity usage, which was around 228.6 MWh in 2014.The average electricity demand in 2014 was approximately 0.69 MW and aggregate peak demand never exceeded 1.81 MW.

The Mamaroneck microgrid will sell electricity from the natural gas generator at the average Con Ed electric supply charge, $78.1/MWh. The proposed generation will include a 1.5 MW natural gas generator and a 0.125 MW solar PV array. The natural gas generator will produce 11,169 MWh of electricity per year, which is enough for nearly all of the microgrid's electricity.[73] Fuel is the main operating cost for the natural gas generator. Assuming a natural gas price of $5.74/Mcf, fuel will cost the Mamaroneck Microgrid approximately $53/MWh. Maintenance costs for the proposed solar array amount to around $34/MWh.

Capital and installation costs associated with proposed DER resources and microgrid components will amount to around $3.17 or $5.24 million (utilizing overhead or underground powerline installation, respectively). The Project Team estimates that installed costs will total $1.95 million for the natural gas generator, $300,000 for the solar array, $667,000 for all microgrid components and control infrastructure, and $235,000 or $2.3 million for overhead or underground powerline installation, respectively. Most microgrid components have an estimated lifespan of 20 years, with the notable exception of the control center, which will need to be replaced in 7-8 years. Planning and design costs will total $1 million. Operation of the microgrid in island mode will include some additional fuel costs (from expanded operation of natural gas generators), but most operational costs will remain constant.

Generation from the proposed DERs and existing backup generators will provide 100% of the microgrid's electricity needs during an outage, maintaining critical services to Mamaroneck's 29,000 residents.

[73] Although the natural gas generator can produce more electricity than the microgrid facilities need over the course of a year, there will be times when peak demand in Mamaroneck exceeds its capacity. At these times the 0.125 MW solar array and 0.2 MW diesel backup generator will provide supplemental electricity.

5.1 Lessons Learned and Areas for Improvement

The lessons learned from the Mamaroneck microgrid feasibility study are divided into two parts. The first part in Section 5.1.1 highlights Mamaroneck-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 stakeholder groups. These lessons learned may be generalized and applied across the state and NY Prize communities.

5.1.1 Mamaroneck Lessons Learned

The development of the Mamaroneck microgrid proposal yielded several important issues to be addressed moving forward and lessons that can inform future microgrid development in the community. Mamaroneck's government supports the microgrid project and has been highly engaged throughout the process. The close communication between the Project Team and the community has been instrumental in refining the project concept to a proposal with which the Town, Con Ed, and the Project Team are comfortable.

As the local utility, Con Ed has an important role in the development of the Mamaroneck microgrid concept. The feeder structure in Mamaroneck is not particularly conducive to a broad microgrid with numerous and diverse facilities. Though the current design proposal includes three critical facilities that serve different purposes, the community is interested in an expanded footprint to include the Westchester Jewish Center, located geographically between the Town Hall and the Sarah Neuman Center. While the Project Team does not object to this addition, Con Ed's recommended approach did not consider this facility in Phase I. This facility will be more closely analyzed for inclusion in Phase II pending more extensive conversations with Con Ed regarding their comfort with expanding the footprint of the microgrid.

Generation options in the Mamaroneck footprint are limited. Though there is natural gas availability the Project Team is not aware of a steam off-taker adjacent to the microgrid footprint. As discussed below, this impacts project economics both due to the lack of steam sales and investment credits but also through the inability to take advantage of the lessened regulatory burden of CHP facilities relative to those lacking a thermal off-taker. Solar installations are likewise constrained because there is insufficient space for expansive PV. The community is a densely developed suburb with limited open space, and the most extensive open space within the footprint is reserved for athletic fields and community recreation. This limits PV installations to small, ground-mounted or roof-mounted arrays, which are not conducive to megawatt plus sizing. The issue of space availability cannot be mitigated in the current footprint.

A further option for generation is a fuel cell installation. Fuel cells are more efficient in their conversion of source fuel to electricity and generate far fewer emissions per unit of energy, however they have exceptionally high capital costs. The Project Team estimates that fuel cells are perhaps triple the cost of natural gas reciprocating generators, and at that level the improved efficiency does not recover the increased cost. The only existing incentive for fuel cells is the Federal investment tax credit (ITC), which will sunset at the end of 2016 and on its own does not provide sufficient subsidy to offset the high capital costs. The recently expired NYSERDA fuel cell rebate program for large fuel cells would likely have provided sufficient support to allow for an economically feasible installation, given the value and timing of the rebate[74], however without it, fuel cells are not cost competitive.

In terms of challenges, the costs of a community microgrid complete with on-site generation and a full suite of new control and network infrastructure are quite high. If the local intention for distributed energy resource assets is to serve a large number of facilities, the capital expenditure may become burdensome. Without relatively larger generation assets, minimum economies of generation may not be reached, and the costs of the control infrastructure may not be recovered. In the absence of the NY Prize, the financial case for Mamaroneck relies on rebates and incentives that may not be available in the long term. And while expanding the footprint is theoretically feasible, the Project Team is not aware of Con Ed's appetite to expand the footprint at this time.

The Mamaroneck microgrid, as proposed in this document, exists with the consent and support of Con Ed and within the Project Team's understanding of current regulatory and legal considerations. The proposed microgrid exists as a set of generation assets that will sell electricity either to Con Ed via a long-term power purchase agreement to Con Ed's main grid or to the facilities under a direct power purchase agreement relationship pending further review on the legality of leveraging that contracting mechanism as discussed below. This structure was proposed because it is viable under current policy[75]; however, slight changes in the New York PSC's PSL §§ 2(2-d) and the Federal Public Utility Regulatory Policies Act could support a business model to facilitate behind-the-meter operation that is economically more advantageous and in line with the intent of the NY Prize and NYSERDA effort to develop community microgrids. The financial viability of many community microgrids would be significantly enhanced if the PSC were to include community microgrids as eligible for QF designation or, absent that change, if the PSC were to provide affirmatively lightened regulation[76] for primarily natural-gas fired projects.

See Appendix for additional information on the QF concept in Mamaroneck.

5.1.2 Statewide Lessons Learned

Through the process of developing deliverables for multiple communities over several months, the Project Team discovered and considered new questions regarding 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.

---

[74] Year 0 rebate of up to $1,000,000.

[75] Under existing law and Commission guidance, the Mamaroneck microgrid will be treated as an electric corporation under Public Service Law unless it is deemed a qualifying facility under the terms of PSL §§ 2(2-d).

[76] CHP, hydro, PV, fuel cells, etc. are already qualifying generation for a QF. Standalone natural gas (turbine or recip.) provides reliable baseload power, and is largely more flexible than the currently included generation types, but is currently excluded. Many locations cannot leverage steam loads and may not have the space available for sufficient PV installations, thus limiting the effectiveness of the QF regulatory status.

Technical. The existing electrical and natural gas infrastructure, along with the permissiveness of the utility in feeder modifications, are the chief determinants of what is possible. In Mamaroneck, the potential design was somewhat narrow given the placement of critical facilities relative to the electrical feeder system and Con Ed's preference for a small footprint. The Mamaroneck system design relies on a new line between the High School and the Sarah Neuman facility; while linking multiple feeders with new lines is not the ideal solution, the proposal satisfies both the NYSERDA requirements to connect multiple critical facilities with different owners, and the Con Ed electrical system requirements. In general, for reasons of power flow, redundancy, and general system operations, connecting feeders is not the first choice but given the support of the utility it can be an effective one. These constraints limit the number and diversity of facilities that may be connected in the microgrid, as the feeders do not always follow expected alignments. Further, and with good reason, utilities generally required proposed microgrids to be placed on the ends of feeders; Sarah Neuman is not on the end of a feeder and a new line will be built to ensure customers downstream of Sarah Neuman are not disconnected. The practical reason for this is to avoid isolating non-microgrid facilities downstream of the microgrid, which could cause power supply problems for the non-connected facilities and therefore be a liability for the utility. This is an understandable concern, and while it will necessarily limit the footprint of many microgrid proposals, the workaround in Mamaroneck may serve as an example of selective facility connection absent AMI meters.

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 given the high costs of storage and biomass and the larger footprints required for wind. Because solar generation is intermittent and has a 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. Natural gas-fired generation, on the other hand, provides high reliability baseload, is relatively clean and efficient, and allows for cogenerated steam sales if there is a proximate off-taker. Moreover, solar requires several orders of magnitude more space than containerized natural gas units, rendering large solar generation infeasible in suburban or urban settings. Mamaroneck has relatively little space available for solar PV; indeed, the only large, open spaces within the footprint are athletic fields that cannot be overtaken by a solar installation.

Financial. Across the portfolio of communities managed by the Project Team, natural gas availability and steam off-takers are the leading elements of financially viable projects. Simply, natural gas generation is more cost efficient, and provides highly reliable revenue streams through electricity sales, and offers steam sales as an added revenue stream unavailable to a system that relies on PV. Unfortunately, there is no steam off-taker in Mamaroneck to justify the construction of a CHP unit, and the project financial feasibility reflects this absence of steam revenue. Additionally, given the currently high cost of battery storage options, it is difficult to make a compelling case for a small solar PV-battery system as a reliable baseload option.

Project financial structures are also important to consider. Revenue from these projects is driven almost exclusively by the sale of electricity and, if available, steam; however, the microgrid control components may require a million dollars or more of capital investment. Ownership structures that separate cost drivers from the revenue streams may be difficult propositions, as the microgrid controls owners would have little opportunity to recoup their investment. This is especially true for privately owned microgrids in locations with reliable power supplies where islanding would be infrequent. In these cases, municipal ownership of the generation and infrastructure would be the most effective. The exception is if the entire microgrid can be developed behind the meter. While it remains to be seen if utilities will allow this to transpire, a fully behind-the-meter solution in an area with moderate to high electricity prices would likely be a more advantageous financial proposition for connected facilities, as well as for generation and controls owners. Mamaroneck is well positioned for this operational structure; however, as discussed in the Appendix, the current regulatory environment may not support a cost efficient behind-the-meter solution.

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, and the lack of certainty of DR payment levels in the future make potential finance partners hesitant to rely on these revenue streams. For instance, interpretations of the existing NYISO DR programs suggest that microgrids could receive 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. While the nature of DR payments in such situations is not clear, the Project Team suggests explicit guidance from the Public Service Commission (PSC) and the various utilities regarding their respective policies. Moreover, during the Mamaroneck Feasibility Study, Con Ed informally communicated they did not expect DR payments to be available for microgrids that simultaneously shed load and generation from the grid. Due to this lack of clarity, DR revenue has generally been excluded from the Project Team's revenue analysis.

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 Mamaroneck, the Project Team has had a strong working relationship and open communication with officials from the community. This type of engagement is not only necessary to build support among prospective facilities but also to engage on ownership models, generation options, and other considerations directly affecting the feasibility of the proposal. In communities with relatively less engagement, it is somewhat 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, as defined in the technical lessons learned section above, is a key factor determining whether the microgrid can be expanded. At some point of expansion, it becomes necessary to link multiple feeders, which means having proximate feeders of the same voltage and connected to desirable facilities is also important. Though this proposal connects two feeders, there is an upper limit to how extensively Con Ed will allow a microgrid to rewire their system. Second, widespread AMI infrastructure makes expansion less complicated and allows facilities that are not microgrid participants to be disconnected selectively. There are no AMI meters in the Mamaroneck footprint, making new lines necessary and excluding the possibility of immediately including several intermediate loads. Lastly, the larger the microgrid grows, the more switches and controls will need to be installed, connected, and maintained to allow for a smooth islanding and grid-reconnect process. In the aggregate, such infrastructure is costly and does not provide many direct returns. Utilities are likely to push back if microgrids grow to occupy significant portions of their infrastructure. To that end, the Project Team has worked diligently with the utilities to find acceptable footprints that both meet the goals of NYSERDA while respecting the operational concerns of local utilities that the NY Prize footprints remain somewhat contained.

5.1.3 Stakeholder Lessons Learned

Developers. Many of the NY Prize project proposals will rely on the Phase III award to achieve positive economics, and still others will remain in the red even with the grant. At this time there is no incentive for developers to participate in the build-out or operation of proposed microgrids that demonstrate negative returns. The potential for developer involvement is highest in communities with relatively high electricity prices and the presence of steam off-takers because these conditions drive project profitability. Mamaroneck, in Westchester County, has high electricity prices but no steam off-taker. Many municipalities are interested in part or full ownership of the microgrid projects, but either they do not have available funds or they 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.

Lastly, and specific to the NY Prize structure, both communities and developers have expressed ambivalence about financing Phase II of NY Prize. There is no assurance that a Phase III award will follow Phase II, and therefore the risk attached to the Phase II cost share is higher than it might be with an assurance of follow on funding.

Utilities. The Project Team and the utilities were frequently involved in a somewhat intractable problem of 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, 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 owner utilities (IOUs) in the Project Team's portfolio, including Con Ed in Mamaroneck, were uniformly against allowing a third party operational control of utility-owned infrastructure. While this view is understandable, it creates a difficult situation if the utility does not support the microgrid development. In such situations, the microgrid will generally be forced to construct duplicative infrastructure, with is both prohibitively expensive and against the spirit of the NY Prize. 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 two areas. First, research into a relatively small grid system with multiple generators (some spinning, some inverter-based), temporally and physically 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 it 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.

Communities. Engaged communities are important, but so too are realistic expectations of what a microgrid might include. Many communities had expectations of dozens of facilities, or entire towns, included in the microgrid without an understanding of 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 Project Team's ability to provide deliverables to NYSERDA on the original schedule.

Second, microgrid control infrastructure is expensive, and distributed energy resources require some scale to become revenue positive enough to subsidize the controls. Therefore, many NY Prize project proposals are not financially feasible without the NY Prize and myriad other rebate and incentive programs. In practical terms, this means, while the NY Prize is unlikely to spur unbridled growth of community microgrids in the state without policy changes, it will create a new 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. 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 industrial facilities remain operational during grid outages, and support the goals of New York's REV.

5.2.1 Environmental Benefits

New York State's generation mix is very clean, with primary energy sources being hydropower and nuclear. Therefore, having a microgrid primarily powered by a natural-gas fired reciprocating engine will increase the overall emissions per kilowatt hour (kWh). However, natural gas is cleaner than most peaking assets, usually coal plants, which come online when statewide demand is high. When coupled with the proposed solar PV array, the Mamaroneck microgrid moves New York towards a clean, distributed energy future.

5.2.2 Benefits to Local Government

The Town government will benefit from the expansion of local, distributed energy resources that will help create a more resilient grid in the area. In the short term, the proposed microgrid will supply electricity to three facilities that provide critical and important services to the community, including the Town government and police, a large shelter in the local high school, and an elderly residential facility. The availability of these facilities in an emergency situation will provide numerous public safety benefits to the Town. The Project Team met by phone with the community on March 10, 2016 to provide a summary of the project analysis and recommendations for a path forward.

5.2.3 Benefits to Residents of Mamaroneck

Residents of Mamaroneck stand to gain from access to shelter and emergency and municipal services during an outage on the grid. In addition, life-support services at the Sarah Neuman Center will be supported by the microgrid. Supporting the resiliency of an elder care facility is in the social good, even though this facility is not public. At present, these services are partially or wholly unavailable during outages; the proposed microgrid provides for unencumbered electrical service to the aforementioned facilities during a grid outage.

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 Mamaroneck microgrid will provide a proof of concept of ownership and operation of microgrids in IOU service areas. It would further make the case for the flexibility associated with microgrids that are not restricted to a single feeder in a sequential arrangement. 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 Mamaroneck microgrid is technically feasible, and it is financially feasible with the award of the Phase III NY Prize or similar grant funding, or an affirmative ruling that the microgrid will be regulated similarly to a Qualifying Facility. Previous sections have detailed 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 as outlined in the SOW for this contract.

The primary risk of the Mamaroneck microgrid project is financial; without grant funding or a change in regulatory treatment, project economics are unfavorable. The current proposal with three facilities was developed in conjunction with Con Ed to minimize disruption to the Con Ed network while also meeting the NYSERDA required project elements. However, the small scale means there is commensurately less generation revenue to offset the installation of control infrastructure and lines.

This microgrid project will help accelerate New York State's transition from traditional utility models to newer and smarter distributed technologies. 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 distributed energy resource assets. The utility will see increased revenues and grid performance, customers will see stabilized electricity and steam prices provided by a more reliable grid system, the community will reap the positive benefits of living in and around the microgrid, and industrial customers will benefit from reduced energy costs and the value of avoided outages. For these reasons, the Project Team recommends this project for consideration as a Phase II NY Prize community.

Path Ahead

Beyond New York Prize, Mamaroneck has several options available to improving energy resilience in the community through energy efficiency, distributed energy resources, and advanced technology such as microgrid controllers. The community has done an exceptional job with energy efficiency and other environmentally beneficial, resilient programs to date and an expansion of the programs will continue to benefit the community absent a microgrid. The myriad programs outlined in previous sections will all either reduce loads, such as expanded solar under the state unified permit and Solarize, or improve energy efficiency, such as the work completed with Honeywell at the schools and municipal buildings.

Encouraging Sarah Neuman to adopt available programs, many of which are Con Ed and NYSERDA programs and listed below, will continue to improve local energy resilience by decreasing loads and improving efficiency. NYSERDA also maintains additional resources, such as the NYSERDA Economic Development Growth Extension (EDGE). The contractor for this effort in Westchester is Melissa Herreria at Courtney Strong, Inc. They hosted a number of webinars and information sessions about NY-Prize in the Mid-Hudson region to encourage municipalities to apply for benefits. Their role is to raise awareness of NYSERDA programs and help utility customers, including municipalities, apply to those programs.

The New York Power Authority (NYPA) provides competitive financing for electric projects such as microgrids for loads at municipal facilities. In Mamaroneck, the High School and the Town municipal building would be eligible for low-rate NYPA financing.

In addition to reducing peak loads as a means to energy resilience, distributed energy resources are often a positive value proposition; indeed the returns on standalone generation in Mamaroneck are positive. While 1.5 MW of continuous, on-site generation may not be a priority for the Town, similar or smaller natural gas reciprocating units would provide increased energy security and, if utilities on a continuous basis, would be a net positive investment. Moreover, the continued expansion of Mamaroneck's already robust solar posture will effectively reduce peak loading on the system as distributed solar flattens some of the system demand curves.

Appendix

Metering data for typical 24-hour load profiles were provided by Con Ed. They are included in this feasibility study to show which facilities have the 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. Con Ed does not provide interval data for loads less than 500 kW, so the Project Team used a simulator to profile typical 24-hour load curves for these facilities. Further, by knowing precisely when load demands are at their peak, the team was able to formulate a peak shaving program to efficiently manage the system.

REDACTED PER NDA WITH CON ED

Business Model, Legal, and Regulatory Commentary

The Mamaroneck microgrid, as proposed in this document, exists with the consent and support of Con Ed and within the Project Team's understanding of current regulatory and legal considerations. The proposed microgrid exists as a set of generation assets that will sell electricity to Con Ed via a long term PPA, providing load agnostic support to the Con Ed grid. This structure was proposed because it is viable under current policy[77], however, slight changes in New York Public Service Commission (NYPSC) PSL §§ 2(2-d) and the Federal Public Utility Regulatory Policies Act could support a business model to facilitate "behind-the-meter" operation that is economically more advantageous and in line with the intent of NY Prize and the NYSERDA effort to develop community microgrids.

The financial viability of many community microgrids would be significantly enhanced if the PSC were to include community microgrids as eligible for QF designation or, absent that change, if the PSC were to provide affirmatively lightened regulation[78] for primarily natural-gas fired projects. Qualifying Facilities must meet certain tests regarding generation type and size, distance, and number of users.

A "behind-the-meter" microgrid would provide significantly stronger returns to investors, propel NY State in the direction of a "grid of grids," and provide more opportunities for load support and demand response across the state. This solution would allow generation assets to load follow the facilities within the microgrid, selling power closer to retail rates to the associated facilities which will result in greater revenues. Excess power may be sold to Con Ed when the locational-based marginal price (LBMP) is greater than the variable cost of production, and the potential exists to generate additional revenue through participation in DR programs. This solution, we believe, requires the microgrid to be treated as a Qualifying Facility. At present, we do not believe that the Mamaroneck microgrid would be eligible as a Qualifying Facility and would instead be subject to regulation as an electric utility (perhaps under lightened regulation, but nonetheless a significant administrative burden given the scope of the footprint).

Under current policy, Qualifying Facility status is based on the distance between facilities and generation, the number of users, the size of generation, and the generation mix. Mamaroneck, as proposed, meets the distance test, which has been held to be approximately two miles or less.[79] The project also meets the number of users test. In *Burrstone*, petitioners raised the question of whether a Qualifying Facility may distribute power to three different institutional users – a hospital, college, and nursing home. The Commission found that "furnishing electric service to multiple users" is specifically contemplated in PSL §2(2-d) "by providing that electricity may be

[77] Under existing law and Commission guidance, the Mamaroneck microgrid will be treated as an electric corporation under Public Service Law unless it is deemed a qualifying facility under the terms of PSL §§ 2(2-d).
[78] CHP, hydro, PV, fuel cells, etc. are already qualifying generation for a QF. Standalone natural gas (turbine or recip.) is currently excluded and many locations cannot leverage steam loads and may not have the space available for sufficient PV installations. It provides a reliable baseload and is more flexible than any of the currently included generation types.
[79] Case 93-M-0564.

distributed to 'users,' in the plural."[80] The Burrstone Energy Project was held to qualify for regulatory exemption. The *Burrstone* case is the only existing precedent of the Commission applying the "Qualifying Facility" standard to more than one user. One interpretation of this precedent might conclude that no upper bound exists on the number of users that may be served by a qualifying facility. This interpretation, however, may prove unwisely speculative. However, we believe the three facilities, and potentially a fourth, would be eligible[81]. The generation size proposed, of 1.625 MW, is well below the 80 MW threshold.

Qualifying status further requires qualified generation; this includes, among others, solar PV and CHP, but not natural gas reciprocating generators. Though the Mamaroneck proposal includes PV, it has a non-CHP natural gas reciprocating engine that is ineligible. We recommend, that for the purposes of community microgrid propagation in New York and elsewhere, and in alignment with REV, that community microgrids themselves (as defined by New York State or FERC) be treated by the PSC as qualifying facilities or other affirmatively more favorable regulation. We believe this change is an important step in the expansion of community microgrids in NY State.

Investor owned utilities are not currently incentivized to allow large swaths of their customer base to move off of their network. The three facilities included in the microgrid proposal represent approximately $300,000 in transmission and distribution charges to Con Ed each year above and beyond the cost of the electricity itself. At a state level, this could easily sum to many millions of dollars of revenue not earned by IOUs. Nevertheless, such a proposal would improve the operation of the NYISO system by optimizing load and generation matching and, if implemented at a large scale, significantly reduce congestion on major transmission infrastructure. As more microgrids populate the region, Con Ed is well positioned to serve as the distributed system platform in its service territory to integrate multiple microgrids, aggregate excess generation capacity, and redistribute services to voltage or watt deficient microgrids, municipal grids, and load pockets. With a critical mass of microgrids or other individually managed load pockets, investor owned utilities will be needed to constantly manage and balance the grid and will yield income on wheeling and the transactions necessary to facilitate such operation.

Thus, slight changes to existing Qualifying Facility designations will greatly help achieve a "grid of grids" concept in the future. While many microgrids may already be eligible for qualifying facility designation, uncertainty about any given project's regulatory disposition drives up costs. The team believes energy costs in New York State, and the current condition of the electricity infrastructure in the State, are ripe for an economically efficient expansion of a system of microgrids, however they remain an elusive proposition without alterations in policy.

[80] Case 07-E-0802 - Burrstone Energy Center LLC – Petition For a Declaratory Ruling That the Owner and Operator of a Proposed Cogeneration Facility Will Not Be Subject to Commission Jurisdiction (August 28, 2007).
[81] It would be further advantageous if the policy adjustments for microgrids would affirmatively allow a larger number of facilities to be served than under the current test.