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Notice

City of New Rochelle Microgrid Feasibility Study

Microgrid Project Results and Final Written Documentation

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Notice

Abstract

Together with the City of New Rochelle (New Rochelle) and Consolidated Edison (Con Ed), Booz Allen Hamilton has completed the feasibility study for a proposed microgrid. This study summarizes the findings and recommendations, results, lessons learned, and benefits of the proposed microgrid. The Project Team has determined the project is technically feasible, though not without challenges. The project is not commercially and financially viable as proposed, and a detailed analysis of both the technical and financial viability can be found in this report. The New Rochelle microgrid project faces the challenge of high capital costs and distant facility clusters, 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 New Rochelle while lessening dependence on existing diesel backup generation. 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 resilience, clean energy, DER, New Rochelle

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Acronyms and Abbreviations

AC	Alternating Current
AMI	Advanced Metering Infrastructure
ATS	Automatic Transfer Switch
BCA	Benefit Cost Analysis
BEMS	Building Energy Management Systems
BTU	British thermal unit
CAIDI	Customer Average Interruption Duration Index
CHP	Combined Heat and Power
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	Locational-Based Marginal Price
LED	Light-Emitting Diode
Mcf	One Thousand Cubic Feet of Natural Gas
MCS	Microgrid Control System
MHz	Megahertz
MMBTU	One Million British Thermal Units
$MMTCO_2e$	Million Metric Tons CO_2 Equivalent
$MTCO_2e$	Metric Tons CO_2 Equivalent
MW	Megawatt
MWh	Megawatt-hour
NPV	Net Present Value
NYISO	New York Independent System Operator
NYPSC	New York Public Service Commission

NYS DEC	New York State Department of Environmental Conservation
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation and Maintenance
OPC	Open Platform Communication or OLE (Object Link Embedded) Process Control
OPF	Optimal Power Flow
PCC	Point of Common Coupling
PLC	Programmable Logic Controller
PPA	Power Purchase Agreement
PSC	Public Service Commission
PV	Photovoltaic
RAID	Redundant Array of Independent Disks
REV	Reforming the Energy Vision
QF	Qualifying Facility
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
VAC	Volt Alternating Current

Executive Summary

Booz Allen Hamilton was awarded a contract by the New York State Energy Research and Development Authority through its New York Prize initiative to conduct a Feasibility Study of a community microgrid concept in the City of New Rochelle. 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 City can improve energy resilience 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 an aggregate 3.7 megawatts (MW) of clean energy generation capability. The study concludes the technical design is feasible.

The New Rochelle microgrid project will tie together generation and facilities in two clusters: the three facilities that comprise the United Hebrew Complex, and Iona College. These are physically and electrically separate clusters that will be connected by the microgrid control system (MCS). 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 New Rochelle.

Table ES- 1. Prospective Microgrid Facilities

Table lists the facilities in New Rochelle's proposed microgrid.

Name	Location	Description	Address
Load	Iona College	Iona College	715 North Ave
F1	United Hebrew Complex	United Hebrew Geriatric Center	391 Pelham Rd
F2	United Hebrew Complex	Willow Towers Assisted Living	355 Pelham Rd
F3	United Hebrew Complex	Low-Savin Residence	40 Willow Dr

In order to meet the energy needs of these critical and important facilities, the microgrid system will incorporate the existing and proposed generation assets in Table ES-2.

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 Iona College and United Hebrew. The backup power provided by the microgrid will ensure shelter and elderly care remain accessible in the event of a long-term grid outage. Both the natural gas generators and the photovoltaic (PV) arrays will operate in islanded and grid-connected mode, pushing electricity to the Con Ed grid via a long-term power purchase agreement (PPA).

Table ES- 2. Microgrid Generation Assets

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

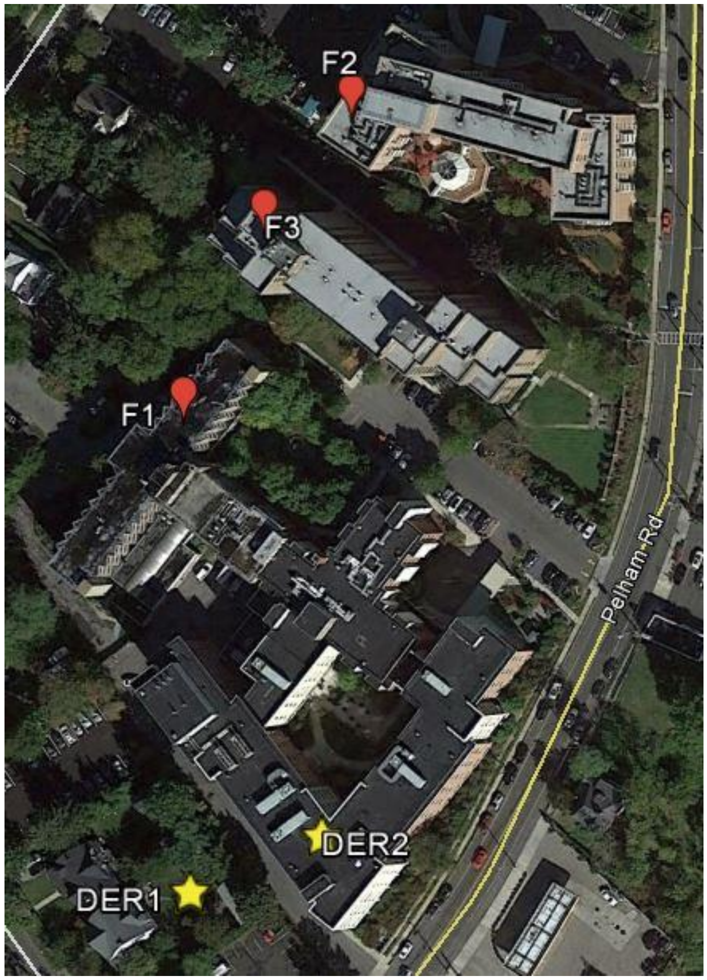
Name (on map)	Location	Description	Fuel Source	Capacity (kW)	Address
DER1	Iona College	New solar PV system	Sun Light	300	715 North Ave
DER2	Iona College	New reciprocating generator	Natural Gas	1,600	715 North Ave
DER3	Iona College	Existing backup generator	Diesel	230	715 North Ave
DER4	Iona College	Existing backup generator	Diesel	285	715 North Ave
DER5	Iona College	Existing backup generator	Diesel	100	715 North Ave
DER6	Iona College	Existing backup generator	Diesel	75	715 North Ave
DER7	Iona College	Existing backup generator	Diesel	150	715 North Ave
DER8	Iona College	Existing backup generator	Diesel	75	715 North Ave
DER9	Iona College	Existing backup generator	Diesel	125	715 North Ave
DER10	Iona College	Existing backup generator	Diesel	125	715 North Ave
DER11	Iona College	Existing backup generator	Diesel	350	715 North Ave
DER12	Iona College	Existing backup generator	Diesel	125	715 North Ave
DER1	United Hebrew Complex	New solar PV system	Sun Light	300	391 Pelham Rd
DER2	United Hebrew Complex	New reciprocating generator	Natural Gas	1,500	391 Pelham Rd

Figure ES-1. Schematic of Iona College Cluster

Figure shows the proposed microgrid at Iona College and the locations of facilities and DERs.

Figure ES-2. Schematic of United Hebrew Complex

Figure shows the proposed microgrid at United Hebrew Complex and the locations of facilities and DERs.



The host facilities, private investors, and the municipality will own the microgrid through special purpose vehicles (SPVs) for 1) the DERs and 2) the infrastructure. The model will maintain the current Con Ed billing and rate capture mechanisms, and revenues cover variable costs, however annual revenue of $1.75 million will not cover capital expenditures. The microgrid will incur initial capital costs of $6.9 million as well as operation, maintenance, and fuel costs totaling $1.6 million per year. Private partners and the host facilities are expected to own the DERs and infrastructure and NY Prize Phase III funding is critical to this proposal's viability, however the revenues generated by electric sales will not cover the full capital expenditure even with a Phase III grant, the project is not solvent.

The New Rochelle microgrid concept, with new clean and renewable generation and the integration of existing energy resources, provides the City with an energy resilience solution that is technically sound and, with the NY Prize, financially viable. The ability to island four critical and important facilities will significantly bolster the resilience of the City during emergencies and extended grid outages.

1. Introduction

The City of New Rochelle (New Rochelle) is seeking to develop a community microgrid to improve energy service resilience, accommodate distributed energy resources, stabilize energy prices, and reduce greenhouse gas (GHG) emissions. Working with New Rochelle and Con Ed, a team from Booz Allen Hamilton (hereafter Booz Allen or the Project Team) designed a preliminary microgrid concept that will connect two clusters of facilities to four new generation assets, a 1.6 MW natural gas generator and 300 kilowatt (kW) solar PV array at Iona College, and 1.5 MW natural gas generator and 300kW solar PV array at the United Hebrew Complex. In addition, several existing diesel backup generators at Iona College will add 1.64 MW of peak support. The microgrid will serve two physically and electrically separate clusters of facilities, providing shelter and elder care services to the residents of New Rochelle and surrounding areas. Section 2 of this document describes the configuration further as well as 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 facilities to dedicated distributed energy resources enhance the energy resilience of New Rochelle. 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 privately-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).

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 New Rochelle 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 higher-emissions peaking assets during peak demand events. The City of New Rochelle 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 larger grid's ability to safely, reliably, and efficiently deliver electricity to customers.

New Rochelle and its residents seek to improve the resiliency of energy service, stabilize costs, and lower their environmental footprint. More specifically, the City faces several challenges that could be resolved with a community microgrid:

- New Rochelle has over 13 miles of shoreline, which makes the city particularly vulnerable to storms. The city was also severely impacted by hurricanes Sandy and Irene. Hurricane Sandy destroyed much of the infrastructure and business along the New Rochelle coastline. Other weather factors, including transformer failure, trees, and lightning, have also caused significant interruption to service.
- Electricity prices for New Rochelle are among the highest in New York State. Residential electricity is $0.23/kWh, which is 31% higher than the average for New York and 95% higher than the U.S. average. Industrial electricity is $0.10/kWh, which is 58% higher than both the New York and U.S. averages. A microgrid could serve to stabilize and lower electricity prices.
- The City has a strong interest in sustainability. New Rochelle has an award-winning Sustainably Plan, GreenNR, and the community microgrid would complement and enhance the City's ongoing efforts to promote environmental sustainability, economic growth, and climate resiliency

Existing distribution infrastructure in New Rochelle, and the distance between the clusters, limits the microgrid footprint to two virtually interconnected campus-style microgrids. The two clusters have no physical electrical connection and are only linked via the control system. The microgrid design allows for independent islanding of the two facility clusters, but it also encourages coordination between the Iona College and the United Hebrew Complex. An outage that effects Iona College, for instance, may not impact United Hebrew and Iona would be able island independent of United Hebrew. Both clusters will require microgrid control systems, expanded information technology (IT) cabling, and normal microgrid components such as smart switches and breakers. Proposed facilities will be the only loads between proposed utility line breakers, rendering advanced metering infrastructure (AMI) remote disconnect unnecessary to enter island mode. However, by installing AMI meters with remote disconnect capability in the area, the City of New Rochelle could conceivably expand the microgrid in the future to include nearby grocery stores (e.g. Foodtown near United Hebrew) and gas stations (e.g., Shell near United Hebrew, Mobil near IC).

Proposed natural-gas fired reciprocating generators will provide a safe and reliable source of electricity throughout the year. The reciprocating generators represent relatively inexpensive, clean sources of energy (natural gas emits less greenhouse gases per unit of energy than diesel, fuel oil, and coal) that will immediately reduce the need for the highest emission peaking assets in the State of New York and, more locally, offset the use of the extensive diesel backup at Iona College.

Avoiding outages has significant monetary value to the connected facilities as well as the citizens of New Rochelle—interruptions to the power supply can derail operations, cause damage to machinery, and render direct health/safety equipment ineffective. When the larger grid loses power, the New Rochelle microgrid will disconnect from the larger grid to supply power to critical facilities in the community. 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. New Rochelle, like many cities and 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 the delivery of electricity to the city's critical facilities. Prolonged grid outages create a potentially hazardous situation for all of the city's residents—the microgrid will alleviate some of this danger by providing shelter and basic life support needs (water, heat, and first aid).

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

The NYSERDA statement of work (SOW) 63515 outlines 15 required capabilities and 18 preferred capabilities each NY Prize microgrid feasibility study must address. Table 1 summarizes required and preferred capabilities met by the proposed microgrid design in greater detail.

Table 1. Microgrid Capabilities Matrix

Table lists NYSERDA's required and preferred capabilities and annotations of whether or not the New Rochelle microgrid will meet these criteria.

Capability	Required/ Preferred	Microgrid will meet (Y/N)
Serves more than one physically separated critical facility	Required	Y[1]
Primary generation source not totally diesel fueled	Required	Y
Provides on-site power in both grid-connected and islanded mode	Required	Y
Intentional islanding	Required	Y
Seamless and automatic grid separation/restoration	Required	Y
Meets state and utility interconnection standards	Required	Y
Capable of 24/7 operation	Required	Y
Operator capable of two-way communication and control with local utility	Required	Y
Load following while maintaining the voltage and frequency when running in parallel to grid	Required	Y
Load following and maintaining system voltage when islanded	Required	Y
Diverse customer mix (healthcare and college)	Required	Y
Resiliency to wind, rain, and snow storms	Required	Y
Provide black-start capability	Required	Y
Energy efficiency upgrades	Required	Y
Cyber secure and resilient to cyber intrusion/disruption	Required	Y

[1] Although multiple facilities are served, they are only connected virtually and as such appear as one controllable entity to the microgrid.

Capability	Required/ Preferred	Microgrid will meet (Y/N)
Microgrid logic controllers	Preferred*	Y
Smart grid technologies	Preferred*	Y
Smart meters	Preferred	N
Distribution automation	Preferred*	Y
Energy storage	Preferred	N
Active network control system	Preferred*	Y
Demand response	Preferred	Y[2]
Clean power sources integrated	Preferred	Y
Optimal power flow (OPF)	Preferred	Y
Storage optimization	Preferred	N
PV observability, controllability, and forecasting	Preferred	Y
Coordination of protection settings	Preferred	Y
Selling energy and ancillary services	Preferred	Y
Data logging features	Preferred	Y
Leverage private capital	Preferred	Y
Accounting for needs and constraints of all stakeholders	Preferred	Y
Demonstrate tangible community benefit	Preferred	Y
Identify synergies with Reforming the Energy Vision	Preferred	Y
* Capability is characterized as preferred by NYSERDA but is a required component in this design		

The following section demonstrates how the design concept meets the required and select preferred capabilities provided by NYSERDA in the Statement of Work 63515.

2.2.1 Serving Multiple, Physically Separated Critical Facilities

New Rochelle and the Booz Allen team have identified twenty-one physically separated facilities at Iona College as critical. These will be tied into a virtual microgrid along with three additional non-critical facilities because their operation during an outage or emergency is vital (e.g., assisted living homes). See Table ES-1 for a full list of prospective critical and important facilities to be tied into the microgrid.

In total, the current number of proposed facilities to be included in the microgrid is four. The two footprints are 2.5 miles apart, interconnected separately within each respective footprint via medium voltage distribution, which is owned by Con Ed. These facilities will be networked by Con Ed's WAN, which will allow the microgrid to serve multiple, physically separated facilities. Utilizing Con Ed's WAN and the industry standard protocols--such as Distributed Network Protocol (DNP3), Open Platform Communication (OPC), Modbus, 61850, Inter-Control Center Communications Protocol (ICCP) (IEC 60870-6), and others as required--the microgrid allows remote monitoring and control of the physically separated facilities. The microgrid design is also flexible and scalable to accommodate the addition of or expansion of the microgrid footprints.

2.2.2 Limited Use of Diesel Fueled Generators

Construction of the 1.6 MW natural gas-fired generator unit and 300 kW solar PV array will greatly reduce the need for backup diesel generation at Iona College. Although they will be

[2] The system is technically capable of providing demand response, but it is unclear whether or not microgrids will qualify for DR programs when both load and generation assets are taken off line simultaneously.

included in the microgrid, the diesel generators are not intended for 24/7 continuous duty. Therefore, they will only be activated in islanded mode to support peak load demand and to serve the loads when either the natural gas generator or PV arrays need to be taken out of commission for maintenance.

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 with the capability to switch from grid to islanded mode either manually by an operator or automatically based on grid disruptions and programmed logic. While in grid connected mode (paralleling with the grid), the microgrid will optimize the use of available assets to reduce energy costs when possible and export to the connected grid when and if economic and technical conditions are in alignment.

For example, the proposed natural gas generators and solar PV systems could operate in parallel to the grid under normal operation, reducing New Rochelle's dependence on grid power. In island mode, the solar PV system would function alongside the other generators to meet critical load needs as well. The natural gas and diesel generators could also be capable of operating in parallel with the grid, although it is envisioned that under normal conditions they will remain off.

2.2.4 Intentional Islanding

The microgrid will switch to intentional islanding when grid conditions indicate islanding will result in a more stable and reliable environment. The microgrid will implement safety controls based on New York State standardized interconnection requirements along with the local utility and building codes to protect the safety of others and equipment during all islanding activities.

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 considered ready to implement islanded operation, and it will begin by opening the incoming utility line breakers. Once in the islanding mode, the microgrid controls must maintain the voltage and frequency between acceptable limits and perform load following.

2.2.5 Seamless and Automatic Grid Separation Restoration

The microgrid will automatically disconnect from the main grid and seamlessly reconnect to it after main grid conditions have stabilized using synchronization and protection equipment. The switching will be done by the operator or when monitored operational variables satisfy predetermined conditions.

Additional breakers at the PCCs are required to connect to the new microgrid generation. The control system is capable of triggering the opening or closing during system transitions.

2.2.6 Standardized Interconnection

This microgrid feasibility study will be governed by the NYPSC interconnection standards. Consolidated Edison customers connecting to the grid via DER projects must follow the same New York State Standard Interconnection Requirements as well. See Table 2 for an outline of the most significant state interconnection standards that apply to this microgrid project.

Table 2. New York State Interconnection Standards

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

Standard Category	Description
Common	Generator-owner shall provide appropriate protection and control equipment, including a protective device that utilizes an automatic disconnect device to disconnect the generation in the event that the portion of the utility system that serves the generator is de-energized for any reason or for a fault in the generator-owner's system
	The generator-owner's protection and control scheme shall be designed to ensure that the generation remains in operation when the frequency and voltage of the utility system is within the limits specified by the required operating ranges
	The specific design of the protection, control, and grounding schemes will depend on the size and characteristics of the generator-owner's generation, as well as the generator-owner's load level, in addition to the characteristics of the particular portion of the utility's system where the generator-owner is interconnecting
	The generator-owner shall have, as a minimum, an automatic disconnect device(s) sized to meet all applicable local, state, and federal codes and operated by over and under voltage and over and under frequency protection
	The required operating range for the generators shall be from 88% to 110% of nominal voltage magnitude
	The required operating range for the generators shall be from 59.3 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
Inverters	Direct current (DC) generation can only be installed in parallel with the utility's system using a synchronous inverter
Metering	Need for additional revenue metering or modifications to existing metering will be reviewed on a case-by-case basis and shall be consistent with metering requirements adopted by the NYPSC

2.2.7 24/7 Operation Capability

The project concept envisions natural gas as the main generation fuel source for the community microgrid. 24/7 operation capability will be met through the City's gas distribution pipeline which already extents to all of the facilities at both Iona College and the Hebrew Center.

2.2.8 Two-Way Communication with Local Utility

The new automation solution proposed in this report will serve as a protocol converter to send and receive all data available 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

Power generated either by the rotating sources (the natural gas generators) or inverter based energy sources (the PV systems) will be frequency and phase synchronized with the main grid. This is one of the most fundamental principles allowing power to be generated by multiple power sources. In this and some other respects, a microgrid is a miniature main grid.

2.2.10 Load Following and Frequency and Voltage Stability When Islanded

In islanded mode, the MCS will maintain control of the generating units to maintain voltage and frequency. In addition, the MCS will have to 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 healthcare (with residences) and one college campus. These two footprints were selected by the team working in close collaboration with Con Ed. Expanding the microgrid beyond these facilities would be difficult because of the nature of the electrical distribution lines in New Rochelle (including the redevelopment portion). The team discovered most of the adjacent buildings are on separate electrical feeders. As such, it is cost prohibitive to include other buildings because new cables would need to be run for electrical connectivity and automated switches would be needed to isolate the buildings from separate feeders.

Even though this customer mix is not widely diverse, these facilities provide services that are vital and beneficial to the City of New Rochelle. In addition, it may be possible for more facilities to be connected to the microgrid in the future.

2.2.12 Resiliency to Weather Conditions

Most typical forces of nature affecting New Rochelle 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. Ways to harden the microgrid resiliency include, but are not limited to, implementing line fault notifications and deployment of other sensors to ensure the network is as resilient as possible to storms and other unforeseen forces of nature. The notifications and sensors can facilitate sending the system into island mode earlier relieving strain on the surrounding macrogrid and ensuring customers see no downtime in service. Furthermore, on-site generation will be distributed across the microgrid to ensure the greatest resiliency should outages affect only specific portions of the New Rochelle macrogrid. Neither footprint is reliant on the generation assets of the other footprint of the microgrid.

2.2.13 Black Start Capability

It is envisioned that the natural gas generators at both the Hebrew Center and Iona College, along with the newest existing diesel generator at Iona College (MTU 4R0113DS125), will be equipped with black start capabilities. When the NYISO grid power goes out for New Rochelle, the microgrid controller initiates island mode by orchestrating the predefined black start sequence. The microgrid then enters un-intentional islanding mode. This mode of operation will require the generators to have a DC auxiliary support system (batteries) with enough power to start the generator multiple times in case it fails to start the first time.

2.2.14 Energy Efficiency Upgrades

Energy efficiency (EE) is critical to the overall microgrid concept. New Rochelle has an ambitious and award-winning sustainability plan, GreenNR, which includes reducing annual per capita energy consumption by at least 20% by 2030. A number of initiatives support this goal by promoting increased efficiency, including programs to upgrade exterior lighting and lower the energy use of municipal buildings. There are also a variety of programs that New Rochelle residents can take advantage of in order to save energy and lower the cost of energy efficiency improvements.

The community microgrid would complement and enhance New Rochelle's ongoing efforts to promote environmental sustainability, economic growth, and climate resiliency. The city views a local microgrid as a potentially valuable component of its ambitious transit-oriented development plans, ideally establishing New Rochelle's downtown as a model of energy efficiency and compact, self-sustaining, resilient urban design. In order to accomplish the City's energy goals and reduce loads served by the microgrid,[3] energy efficiency efforts will be focused on facilities in the microgrid concept area.

The Project Team benchmarked and estimated the electricity demand reduction potential in the facilities to be approximately 200 kW. Table 3 provides a list of the potential EE upgrades that will help achieve this targeted reduction. The project will utilize Con Ed's existing EE programs to help implement further EE efforts within the microgrid footprints. The project implementation team will also seek to qualify microgrid facilities for NYSERDA funded EE programs.

[3] GreeNR: The New Rochelle Sustainability Plan 2010-2030.

Table 3. Potential EE Upgrades to Microgrid Facilities

Table provides an overview of the potential energy efficiency upgrades at the following facilities: United Hebrew Geriatric Center, Willow Towers Assisted Living, Low-Savin Residence, and Iona College. Also denotes existing efficiency programs.

Facility	Potential EE Upgrades	Existing Utility EE Program (✓)
United Hebrew Geriatric Center	- Lighting upgrades	✓
Willow Towers Assisted Living	- Fluorescent lights to light-emitting diode (LED) - Upgrade kitchen appliances	✓ ✓
Low-Savin Residence	- Lighting upgrades	✓
Iona College	- Upgrade remaining lights to LED	✓

As part of the process to further energy sustainability in New Rochelle, the microgrid Project Team and New Rochelle will investigate additional EE options and financing mechanisms.

Free and reduced cost energy assessments are available through NYSERDA. Westchester County offers limited-availability free audits, and Consolidated Edison offers an energy survey and energy-saving item installation for a $50 fee. Rebates for EE improvements and equipment are available through Con Ed and NYSERDA programs, up to a maximum of $3,000 depending on eligibility. Energy efficiency loans and financing are also available through NYSERDA Energy Star and the New York Energy $mart Residential Loan Fund.

2.2.15 Cyber Security

The microgrid management and control system network data will be fully encrypted when stored or transmitted. In addition, the microgrid will be protected from cyber intrusion and disruption through the combination of network segmentation broken down by function and the utilization of network firewalls and continuous monitoring. The microgrid management and control system will be set up in such a way that authorized personnel are provided access to the automation system via the control center, while access is denied to unauthorized persons. Also, activating and analyzing security logs may be utilized. As a rule, the operating system and firewall can be configured in such a way that certain events (for example, failed login attempts) are recorded.

2.2.16 Use of Microgrid Logic Controllers

Microprocessor based IEDs serving as microgrid logic controllers are described above in Section 2.7.1. The role of the IED is to provide monitoring and control capabilities at or near the object being controlled. The Project Team believes this is a required capability for the proposed system.

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 for this microgrid.

2.2.18 Smart Meters

The City of New Rochelle does not have smart meters installed throughout its coverage area. While ideal, smart meters are not required for this microgrid because control sequencing is done at the feeders and facility-level.

2.2.19 Distribution Automation

The automation solution outlined in this study for the City of New Rochelle's microgrid includes IEDs that are distributed at or near individual loads. Their role is to control the load and communicate monitored variables to the control system servers for processing, viewing, and data logging. The Project Team believes this is a required capability for the proposed microgrid.

2.2.20 Energy Storage

At this time, battery storage technologies have not been identified as an optimal energy solution for the City of New Rochelle due to their high cost. Despite this, the microgrid 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 city changes its thinking in the future.

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 City's fiber optics backbone partitioned using gigabit Ethernet switches. The Project Team believes this is a required capability for the operation of this system.

2.2.22 Demand Response

The New Rochelle 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 that consistent load reduction will qualify for Con Ed's DR programs.

2.2.23 Clean Power Sources Integration

Currently, the clean power sources include solar PV and natural gas generators. In the future, it may be possible to expand the footprint, or generation assets, to include additional clean power sources. At that time, biomass, battery storage, and fuel cells are all feasible clean power sources that will be explored. More detailed methods to capture and convert energy by electric generators or inverters will be examined at a later time.

2.2.24 Optimal Power Flow (Economic Dispatch)

The City of New Rochelle microgrid is expected to be fairly small, with only a few generation resources. An economic dispatch will comprise of the pre-determined priority list, which will take into account generation availability, balancing run-times, and fuel costs. 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 energy storage is incorporated in the system design, it will include intelligent controls necessary to work in unison with the microgrid controls. The MCS will fully utilize and optimize the storage resources to reduce peak demand and smooth ramping including the charge/discharge management of energy storage.

2.2.26 PV Monitoring, Control, and Forecasting

If solar PV is incorporated into the microgrid, PV inverters will be tied into the MCS and can be controlled to reduce output, either to match load or to better align with simultaneous generation from the diesel of gas units. The microgrid power management includes the ability to integrate high resolution solar forecasting, increasing the value by firming up the PV and smoothing out ramping.

2.2.27 Protection Coordination

Microgrid protection strategies can be quite complex depending on the network topology and possible load and generation amount and distribution. The currently implemented protection scheme is very likely based on the assumption that the power flow is unidirectional and of certain magnitude. Although the bidirectional flow can happen in the grid connected mode, islanding mode of operation might introduce some additional difficulties. The microgrid designer and implementer will perform protection studies accounting for possible bidirectional power flows and very low currents, which can occur when the network is in islanding mode of operation.

2.2.28 Selling Energy and Ancillary Services

It is unclear whether the microgrid will be permitted to back-feed through New Rochelle's main substation into the broader Con Ed transmission system. If allowed, the microgrid is envisioned to sell excess solar energy back to Con Ed.

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. 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, community participants, and other stakeholders is at the center of this feasibility study. The Project Team has engaged and will continue to engage with all parties to understand their specific needs and constraints. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.4.

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 City government, utility, and community groups will ensure a community microgrid will add tangible and scalable value to New Rochelle and the surrounding areas. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.4.

2.3 Distributed Energy Resources Characterization (Sub Task 2.3)

As described above, the proposed microgrid will utilize several DERs in New Rochelle. This section will discuss the benefits of the proposed resources and explain how they will meet the microgrid's demand in greater detail.

2.3.1 Existing Generation Assets

No generation assets at the Hebrew Center were confirmed to be operationally sound enough for inclusion in the microgrid. There is an existing diesel generator at the Hebrew Center; however, it was not confirmed to be operational, nor are there any specifications on it, making it very difficult to include in our proposed design. Additionally, a diesel generator (capacity also unknown) was planned to be installed at Willow Towers after Hurricane Sandy. While planned, the generator was never installed. Additional generators, such as these, may easily be included in the microgrid should they become operational in the future with the addition of appropriate a switchgear and generator controls.

Iona College currently has multiple diesel backup generators. Several factors must be considered when deciding whether or not an existing diesel backup generator should be included in the microgrid. These include generator capacity, load following capability, reactive power generation control, functionality (whether it serves emergency or critical power circuits mandated by code), and location with respect to the loads it is intended to serve. Finally, the use of diesel generators may not be ideal if a clean generation asset is available. Construction of the 1.6 MW natural gas-fired generator unit and 300 kW solar PV array will greatly reduce Iona College's need for diesel generation.

Altogether, there are ten existing diesel generators (totaling 1.6 MW) at Iona College that may be used for peak shaving and to support black-start capabilities of the microgrid. They will provide ample generation capacity 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 for these ten units. All ten generators are currently on a maintenance program and serviced twice annually.

Although they will be included in the microgrid, the diesel generators are not intended for 24/7 continuous duty. Therefore, they will only be activated in islanded mode to support peak load demand and to serve the loads when either the natural gas generator or PV arrays need to be taken out of commission for maintenance.

The existing DERs that will be included in the microgrid are summarized in Table 4.

Table 4. Existing DERs at Iona College

Table displays the names of all existing DERs in Iona College (there are no existing DERs in United Hebrew), including their rating, fuel, and address.

Name	Technology	Rating (kW)	Fuel	Address
Kohler 230ROZ28	Diesel Generator	230	Diesel	715 North Ave
Caterpillar SR-4B	Diesel Generator	285	Diesel	715 North Ave
Detroit 100U	Diesel Generator	100	Diesel	715 North Ave
Detroit B6811	Diesel Generator	75	Diesel	715 North Ave
Kohler 150REZOJB	Diesel Generator	150	Diesel	715 North Ave
GLT 75.0DMT-125	Diesel Generator	75	Diesel	715 North Ave
Onan DGDK5703804	Diesel Generator	125	Diesel	715 North Ave
Cummins DSGAC7612516	Diesel Generator	125	Diesel	715 North Ave
MTU 350PX6DT3	Diesel Generator	230	Diesel	715 North Ave
MTU 4R0113DS125	Diesel Generator	125	Diesel	715 North Ave

2.3.2 Proposed Generation Assets

The two proposed generation assets include a 1.5 MW natural gas-fired, continuous duty reciprocating generator with a 300 kW PV array system at the Hebrew Center and a 1.6 MW natural gas-fired, continuous duty reciprocating generator with a 300 kW PV array system at Iona College, as shown in Table 5.

At the Hebrew Center, the natural gas generator will be located behind the Willow Towers (391 Pelham Road), and the PV array will be located on the roofs of United Hebrew Geriatric Center, Willow Towers, and Low-Savin Residence, pending a professional roof and structural evaluation. Iona College has 43 acres; therefore, while the exact location of the 1.6 MW natural gas generator (approximately 10 feet wide by 40 feet in length) and 300 kW of solar PV (which needs about half an acre) is not yet finalized, the team believes the locations for both generation assets will be finalized during the Phase II design.

Table 5. Proposed Distributed Energy Resources

Table shows a list of the rating, fuels, and addresses of the proposed generation assets.

Iona College DERs				
Name	**Technology**	**Rating (kW)**	**Fuel**	**Address**
Natural Gas Generator at Iona College	Natural Gas Generator	1600 kW	Natural Gas	715 North Ave
PV Array at Iona College	Solar	300 kW	N/A	715 North Ave
United Hebrew DERs				
Name	**Technology**	**Rating (kW)**	**Fuel**	**Address**
Natural Gas Generator at United Hebrew	Natural Gas Generator	1500 kW	Natural Gas	391 Pelham Rd
PV Array at United Hebrew	Solar	300 kW	N/A	391 Pelham Rd

2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics

The proposed design provides the City of New Rochelle with several additional energy resources. In grid-connected mode, the two proposed PV arrays and two proposed natural gas generator units will operate in parallel with the main grid, exporting excess power and importing supplementary power to meet peak demand when necessary. In islanded mode, the PV arrays and natural gas generators will supply the base load with supplementary power from the ten existing diesel generators available at Iona to meet peak loads, if needed. The natural gas generator units and diesel generators are capable of covering the microgrid's demand during island mode, providing power during situations in which the solar PV arrays may be offline due to weather or time of day.

To harden the generation assets, the proposed equipment locations will be placed at elevated areas of each respective footprint not prone to flooding in order to avoid damage and disruptions to power supply. The natural gas pipeline is already buried to protect it from severe weather. Generators will also be protected from rain, snow, strong winds, or falling trees. The team is still determining the best way to protect the existing generators from weather; at minimum, they will be protected by a container.

The portfolio of identified DERs, will be capable of supplying reliable electricity by providing:

- Automatic load following capability – generation units and controls will be able to respond to load fluctuations within cycles, allowing the microgrid system to maintain system voltage and frequency.
- Black-start capability – the natural gas generators will have auxiliary power (batteries) required to start and establish island mode grid frequency.
- Conformance with New York State Interconnection Standards.[4]

[4] 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*.

2.4 Load Characterization (Sub Task 2.2)

Electricity data from New Rochelle's load points is essential to correctly size new power generation. The load characterizations below fully describe the electrical loads served by the microgrid when operating in islanded and parallel modes based on metering data from the facility's account numbers via Con Ed's on-line metering portal. Descriptions of the sizing of the loads to be served by the microgrid, along with redundancy opportunities to account for downtime, are included below.

2.4.1 Electrical Load

Electrical load characterization consisted of analyzing Iona College, United Hebrew Geriatric Center (150 residents), Willow Towers Assisted Living (125 residents), and Low-Savin Residence (150 residents) located within the boundaries of the New Rochelle microgrid footprints. Approximately 500 feet separate United Hebrew, Low-Savin, and Willow Towers. At Iona College, the microgrid covers approximately 24,000 square feet and is located 2.5 miles from the Hebrew Center. These facilities and their loads are summarized below in Table 6. Refer to the **Error! Reference source not found.** for typical 24-hour load profiles for each of the microgrid facilities during a typical month in 2014.

Table 6. City of New Rochelle List of Prospective Microgrid Facilities

Table lists potential microgrid facilities, and their classifications.

Property	Classification
Iona College	School*
United Hebrew Geriatric Center	Residential**
Willow Towers Assisted Living	Residential**
Low-Savin Residence	Residential**
	* Critical Facility ** Important Facility

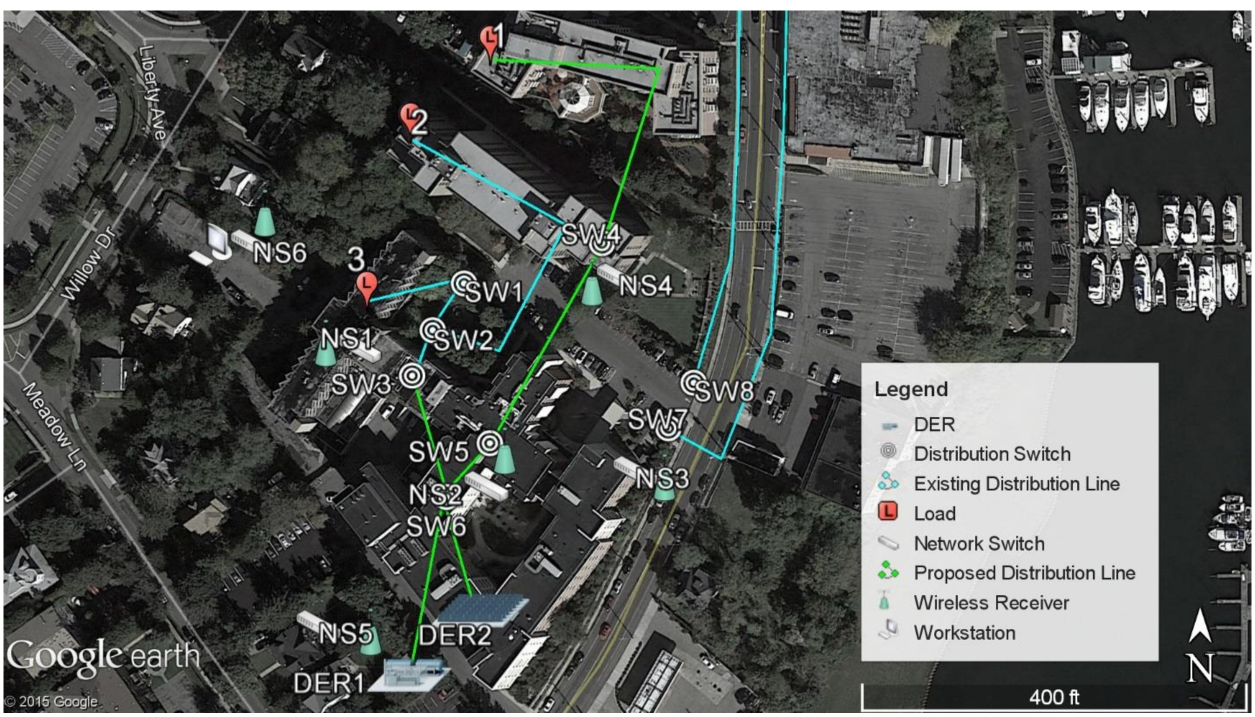
Figures 1a and 1b below provides an illustration of the proposed microgrid design and layout and is referenced throughout the rest of the document.

Figure 1a. New Rochelle Equipment Layout – Iona College

Figure shows the microgrid equipment layout, illustrating proposed man hole, DERs, distribution lines, load points, workstations, network switches, and proposed distribution switches.

Figure 1b. New Rochelle Equipment Layout – Hebrew Center

Figure shows the microgrid equipment layout, illustrating proposed DERs, distribution lines, load points, workstations, network switches, and proposed distribution switches.



The 12 months of metering data for 2014 was provided by Con Ed and is summarized below in Table 7. The total peak load in New Rochelle for all microgrid facilities in 2014 was 3.451 MW, and the monthly average was 1.345 MW. For a cumulative hourly load profile of all loads, see Figure 2.

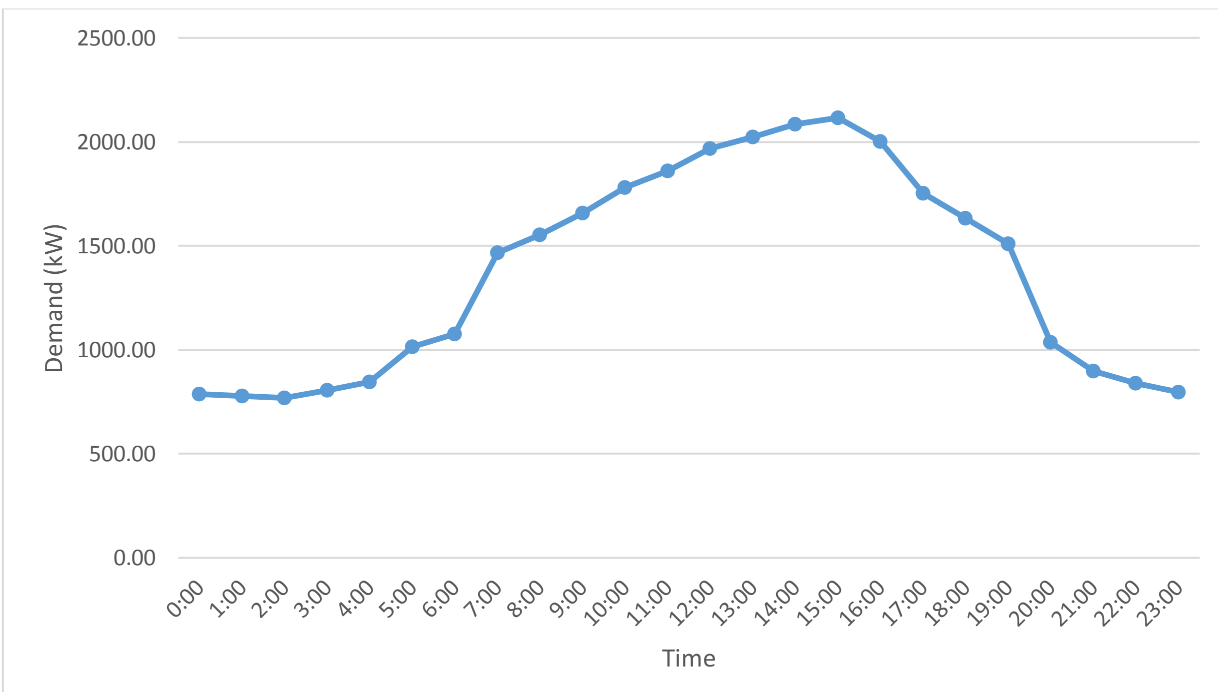
Table 7. New Rochelle's 2014 Microgrid Load Points

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

	Electric Demand (kW)		Electric Consumption (kWh)			Thermal Consumption (MMBTU)[5]		
	2014 Peak	2014 Average	2014 Annual	2014 Monthly Average	2014 Weekly Average	2014 Annual	2014 Monthly Average	2014 Weekly Average
Microgrid Loads	3,451	1,345	11,790,967	982,581	228,507	41,285	3,440	800

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

Figure illustrates the typical 24-hour cumulative load profile in which the system peaks in the afternoon.



The proposed natural gas-fired generators and solar PV arrays will operate continuously in both parallel and islanded mode at the Hebrew Center and Iona College with the exception of prearranged downtimes for service. When the PV arrays do not operate at their full capacity of

[5] Despite the thermal load indicated here, this thermal consumption here is basically heating, done by some system which cannot be replaced by a CHP unit. No sufficient thermal off-taker exists to support a CHP facility in New Rochelle.

300 kW, the 1.6 MW natural gas generator and existing diesel generators (totaling an additional 1.6 MW of generation capacity at Iona College) will be available during islanded operation. Likewise, 300 kW of PV will also be supported by the proposed 1.5 MW natural gas generator at the Hebrew Center.

2.4.2 Thermal Consumption

Thermal consumption for the microgrid facilities are included for reference but are not essential for the microgrid technical design to work as they are minimal and account for only heating. The team did research and made every attempt to propose a CHP or cogeneration unit at the Hebrew Center or Iona College. However, the team discovered there are no steam loads at either location, nor is there a feasible alternative to their existing heating and cooling units that could be served by the microgrid.

2.5 Proposed Microgrid Infrastructure and Operations (Sub Task 2.1)

In order to improve energy resiliency and stabilize energy prices during peak demand events, the microgrid will be able to operate in parallel with the main grid (connected) or while disconnected from the main grid (islanded mode). The microgrid will be equipped with a vendor agnostic Service Oriented Architecture (SOA) framework, and this software messaging platform will enable the microgrid to reliably switch between grid-connected and islanded operation mode in real time. A human operator or programmed logic will determine when the system switches modes. The monitoring and control systems will combine information on power quality, utilization, and capacity in real-time to optimally use available generation and flexible load resources.

A Supervisory Control and Data Acquisition (SCADA) based control center will allow an operator to remotely monitor and control the microgrid processor-based controllers in the field from a single location.

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

In grid parallel (connected) mode, which is the normal mode of operation, the microgrid will operate the proposed 3.7 MW (1.5 MW for United Hebrew and 1.6 MW for Iona College) gas-fired reciprocating engine generator and the proposed 600 kW PV (300 kW for United Hebrew and 300 kW for Iona College) array in parallel with the grid. During grid parallel operation, the proposed DER assets will supply the energy needs of the entire microgrid system because they are built for continuous duty operation. Connections with Con Ed's distribution grid will be maintained for reliability during grid connected mode, although the microgrid control system will minimize the power flows between the systems.

2.5.2 Islanded Mode

In islanded (autonomous) mode, the operating strategy is mainly focused on using an appropriate energy management and control scheme to improve the operation of an islanded microgrid as described in Section 2.7.4 of this document. The two separate controllable loads at Hebrew and Iona are physically separated and on different feeder distribution lines; therefore, intentional islanded control may be desired for one but not the other at any given time. Intentional islanded mode can be utilized during Con Ed grid outages or disturbances, or for economic reasons. The system will manage the 1.5 MW natural gas generator and 300 kW solar PV at Hebrew center. The system can also manage the 1.6 MW natural gas-fired generator and 300 kW solar PV array at Iona College. Real-time response for generation assets is necessary to ensure the microgrid generation is equal to the demand.

2.6 Electrical and Thermal Infrastructure Characterization (Sub Task 2.4)

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

2.6.1 Electrical Infrastructure

At Iona College, electricity enters from feeder 54U4 coming from the Twin Lakes-54 substation. New pad mounted equipment (PME) and manholes (VS19304, VS18396, V19555, and VS9639) are used to connect all of the loads at Iona College to the new express cable running in parallel to the existing lines on South Path, North Avenue, and Hubert Place as illustrated in Figure 3a.

At the Hebrew Center, electricity enters from the primary feeder 20W75 coming from the Cedar Street Substation and then enters an automatic transfer switch (ATS) (V19518). After ATS V19518, a new connection is required to connect the ATS and the proposed PME-9 to a T-Tap Box, more commonly known as a junction or termination point (TT19636), which contains switches 1-3 (SW1-SW3). The 1.5 MW natural gas generator is connected (normally closed) with switch 6 (SW6) on PME-9, enabling the generator to be in grid connected mode. PME-9 is also where the switching enables the microgrid facilities to be islanded from the main grid by opening switch 5 (SW5). The PME-9 feeds Willow Towers (Load V18218) and TT19636 that is used to connect Low-Savin Residence (Load V1303) and the Hebrew Center (Load V19754). All of this infrastructure is illustrated in Figure 3b below.

The following tables (Table 8 to Table 10) describe the microgrid components and are referenced throughout the rest of the document.

Table 8. New Rochelle Distributed Switches Description

Table outlines the distributed switches with their descriptions.

Name in Iona College	Description	New/Upgrade
SW1	Automatic switch for load shedding and microgrid sequence control	New
SW2	Automatic switch for feeder isolation	New
SW3	Automatic switch for feeder isolation	New
SW4	Automatic switch for load shedding and microgrid sequence control	New
SW5	Automatic switch for feeder isolation	New
SW6	Automatic switch for load shedding and microgrid sequence control	New
SW7	Automatic switch for load shedding and microgrid sequence control	New
SW8	Automatic switch for feeder isolation	New
SW9	Generator breaker	New
SW10	Inverter internal breaker	New
SW11	Generator breaker	Upgrade
SW12	Generator breaker	Upgrade
SW13	Generator breaker	Upgrade
SW14	Generator breaker	Upgrade
SW15	Generator breaker	Upgrade
SW16	Generator breaker	Upgrade
SW17	Generator breaker	Upgrade
SW18	Generator breaker	Upgrade
SW19	Generator breaker	Upgrade
SW20	Generator breaker	Upgrade
Name in United Hebrew	**Description**	**New/Upgrade**
SW1	Automatic switch for load shedding and microgrid sequence control	Upgrade
SW2	Automatic switch for load shedding and microgrid sequence control	Upgrade
SW3	Automatic switch for redundancy	Upgrade
SW4	Automatic switch for load shedding and microgrid sequence control	New
SW5	Proposed pad mount switch	New
SW6	Proposed pad mount switch	New
SW7	Automatic switch for feeder isolation	Upgrade
SW8	Automatic switch for feeder isolation	Upgrade
SW9	Generator breaker	New
SW10	Inverter internal breaker	New

Table 9. New Rochelle Network Switch Description

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

Name in Iona College	Description	Status	Location
NS1	Near Switch 5 and Switch 6 for communication	Proposed	Refer to Eqp. Layout
NS2	Near Switch 3 and Switch 4 for communication	Proposed	Refer to Eqp. Layout
NS3	Near Switch 7 and Switch 8 for communication	Proposed	Refer to Eqp. Layout
NS4	Near Switch 1 and Switch 2 for communication	Proposed	Refer to Eqp. Layout
NS5	Near DERs for communication	Proposed	Refer to Eqp. Layout
NS6	Near Workstation for communication	Proposed	Refer to Eqp. Layout
Name in United Hebrew	**Description**	**Status**	**Address**
NS1	Near Switch 1, Switch 2, and Switch 3 for communication	Proposed	Refer to Eqp. Layout
NS2	Near Switch 5 and Switch 6 for communication	Proposed	Refer to Eqp. Layout
NS3	Near Switch 7 and Switch 8 for communication	Proposed	Refer to Eqp. Layout
NS4	Near Switch 4 for communication	Proposed	Refer to Eqp. Layout
NS5	Near DERs for communication	Proposed	Refer to Eqp. Layout
NS6	Near Workstation for communication	Proposed	Refer to Eqp. Layout

Table 10. New Rochelle Server Description

Table contains a description of servers and workstations, their status as proposed, and their addresses.

Name in Iona College	Description	Status	Address
Workstation	Operator/Engineer workstation	Proposed	715 North Ave
Name in United Hebrew	**Description**	**Status**	**Address**
Workstation	Operator/Engineer workstation	Proposed	391 Pelham Rd
Sever1	SCADA / Energy Management System (EMS) Primary	Proposed	391 Pelham Rd
Sever2	SCADA / EMS Secondary	Proposed	391 Pelham Rd

The distribution grid at Iona College and the Hebrew Center is medium voltage and that all loads have their own pole mounted or enclosed transformer which steps down medium voltage to low voltage.

Figure 3a. New Rochelle One-Line Diagram – Iona College

Figure shows the one-line diagram for Iona College in New Rochelle, illustrating interconnections and layout.

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Figure 3b. New Rochelle One-Line Diagram – Hebrew Center

Figure shows the one-line diagram for New Rochelle, Hebrew Center, illustrating interconnections and layout.

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2.6.2 Points of Interconnection and Additional Investments in Utility Infrastructure

The proposed interconnection points and investments in New Rochelle for microgrid operation are listed in Table 11. The proposed point of common coupling between the main grid and the microgrid at Iona College is located at ATS VS19304, VS18396, V19555, and VS9639. The proposed PCC between the main grid and the microgrid at the Hebrew Center is located at ATS V19518.

Table 11. List of Additional Components

Table lists all PCC components as well as distribution devices.

Iona College 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)	4	New breakers/switches at 4 distribution load feeders to isolate microgrid from the utility feed. Fourth breaker to separate the non-critical/non Iona North St. addresses from microgrid.
Automated Load Circuit Breakers (Siemens 7SJ85 relay)	4	New switch at Iona College load circuit breakers for remote monitoring/control to enable load shedding and generator sequential loading
Generation Controls (OEM CAT, Cummins, etc.)	11	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 MGMS 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 high location.
WiMax Subscriber Units	5	Each subscriber unit can communicate back to the WiMax base station for MGMS/MCS monitoring and control or remote relay to relay GOOSE messaging.
United Hebrew Device	**Quantity**	**Purpose/Functionality**
Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay)	2	Update existing switches at 2 distribution load feeders to isolate the microgrid from the utility feed remotely. Separate Con Ed line to Cedar Street Substation from microgrid.
Automated Load Circuit Breakers (Siemens 7SJ85 relay)	3	New switch to Willow Tower and upgrade existing load circuit breakers to Low-Savin Residence and United Hebrew Geriatric Center for remote monitoring/control to enable load shedding and generator sequential loading

Automated PME (Siemens 7SJ85 multi breaker control relay)	1	Pad Mount Enclosure with 2 switches and 2 fuses. To be updated to be automated with remote control relay capable of controlling both switches (generator and ATS). Current sensing on utility infeed allows for the ability to initiate emergency microgrid mode.
Generation Controls (OEM CAT, Cummins, etc.)	1	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 MGMS 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 high location.
WiMax Subscriber Units	5	Each subscriber unit can communicate back to the WiMax base station for MGMS/MCS monitoring and control or remote relay to relay GOOSE messaging.

In order to serve multiple, non-contiguous loads using generators spread across the existing distribution grid, the microgrid will rely on automated isolation switches across the feeders to segment loads by enabling automatic grid segmentation, 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.

All microgrid devices will require a reliable source of DC power. At each device (or grouping of devices in a similar location), there will be a primary and backup power supply source. During normal operation, a 120 volt alternating current (VAC) power source will be sent through an alternating current (AC)/DC converter to power the microgrid devices and maintain the charge of the DC battery bank. When normal AC voltage is unavailable (likely due to an issue outside of or elsewhere in New Rochelle's distribution grid), all microgrid devices will be capable of operating on DC power from the battery 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, such as voltage, current, and frequency, and takes corresponding actions, such as de-energizing a circuit line. Some protection schemes are based on the assumption that power flows in one direction. However, bidirectional power flow during island mode will introduce difficulties for protection coordination because it violates the unidirectional power flow assumption of the existing protection scheme. At a later design stage, the microgrid designer will have to perform protection studies accounting for possible bidirectional power flows and very low currents, which can occur when the network operates in island mode.

Because it is unclear whether the microgrid will be permitted to back-feed through Con Ed's main substations (Cedar Street and Twin Lakes-54) into the broader transmission system, the current proposed design includes controls that have the necessary hardware and protection scheme to prevent back-feeding power into the Con Ed system. However, if selling is allowed, the microgrid is capable of selling excess energy back to Con Ed.

2.6.4 Thermal Infrastructure

The proposed natural gas generators will be fed from an 8 inch medium pressure gas distribution line at the Hebrew Center and an 8 inch low-pressure gas distribution line at Iona College. At a minimum, the natural gas reciprocating engines require 3-5 pounds per square inch gauge (psig) pressure at their intake. The existing natural gas lines at both locations have an adequate supply of natural gas and pressure for the proposed generators.

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 located at the Hebrew Center (see Figure 4). The two footprints are physically separated, but they will appear as one controllable entity to the main microgrid controller. While operating in grid parallel mode, the microgrid will synchronize frequency and phase and has the potential to sell excess electricity to Con Ed according to Con Ed's net metering guidelines. Each microgrid footprint will switch to island mode only in emergency outage situations, maintenance mode, or if economic reasons justify. In these situations, the microgrid will provide power to key facilities through its black-start capabilities. The microgrid will also automatically re-synchronize to the Con Ed grid when power returns after an emergency situation.

A Building Energy Management System (BEMS) is not listed as a required or preferred capability defined in this feasibility study Purchase Agreement between NYSERDA and Booz Allen; however, several of the components that compose a conventional BEMS are already included in the proposed automated microgrid control system (smart meters, solar PV integration, and other monitoring and control via smart technologies). As noted in the Smart Technologies section, the proposed microgrid is Service Oriented Architecture based. This allows for the future addition of building energy control systems (ventilation, lighting, fire, and security) because these components integrate easily using open standards such as Modbus, LonWorks, DeviceNet, and other Transmission Control Protocol/Internet Protocol (TCP/IP) internet protocols.

2.7.1 Microgrid Supporting Computer Hardware, Software, and Control Components

To achieve an automated microgrid, the following is a preliminary list of hardware equipment resources needed for the City of New Rochelle.

- Energy sources – The microgrid requires DERs in order to supply electricity to connected facilities. To some degree, flexible loads that can be reduced during peak demand events may also be considered as energy sources.
- Microgrid Control System – The MCS is composed of an Energy Management System and Supervisor Control and Data Acquisition (SCADA) based control center. The MCS is responsible for logging relevant data, regulating generator output, curtailing flexible loads (where possible), and managing transitions between modes of operation.

- Distribution system – additional electrical distribution lines, automated switches and breakers, and other control elements at or near individual loads across the microgrid
- Additional utility breakers and controls – automatic controls at the interface point between New Rochelle's distribution grid and the existing Con Ed feeders
- Generator controls/relays – installed at each generating unit/inverter. They will control generator output based on signals from the MCS.

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

- SOA software platform – The SOA platform facilitates the monitoring and control of included power devices and control systems.
- 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 – The Historian database collects and logs data from various devices on the network.
- Applications server (one or more) – Depending on the software and hardware vendors' preference, application servers may be used for numerous purposes. Common uses for an application server include (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 SCADA control room 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) – 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

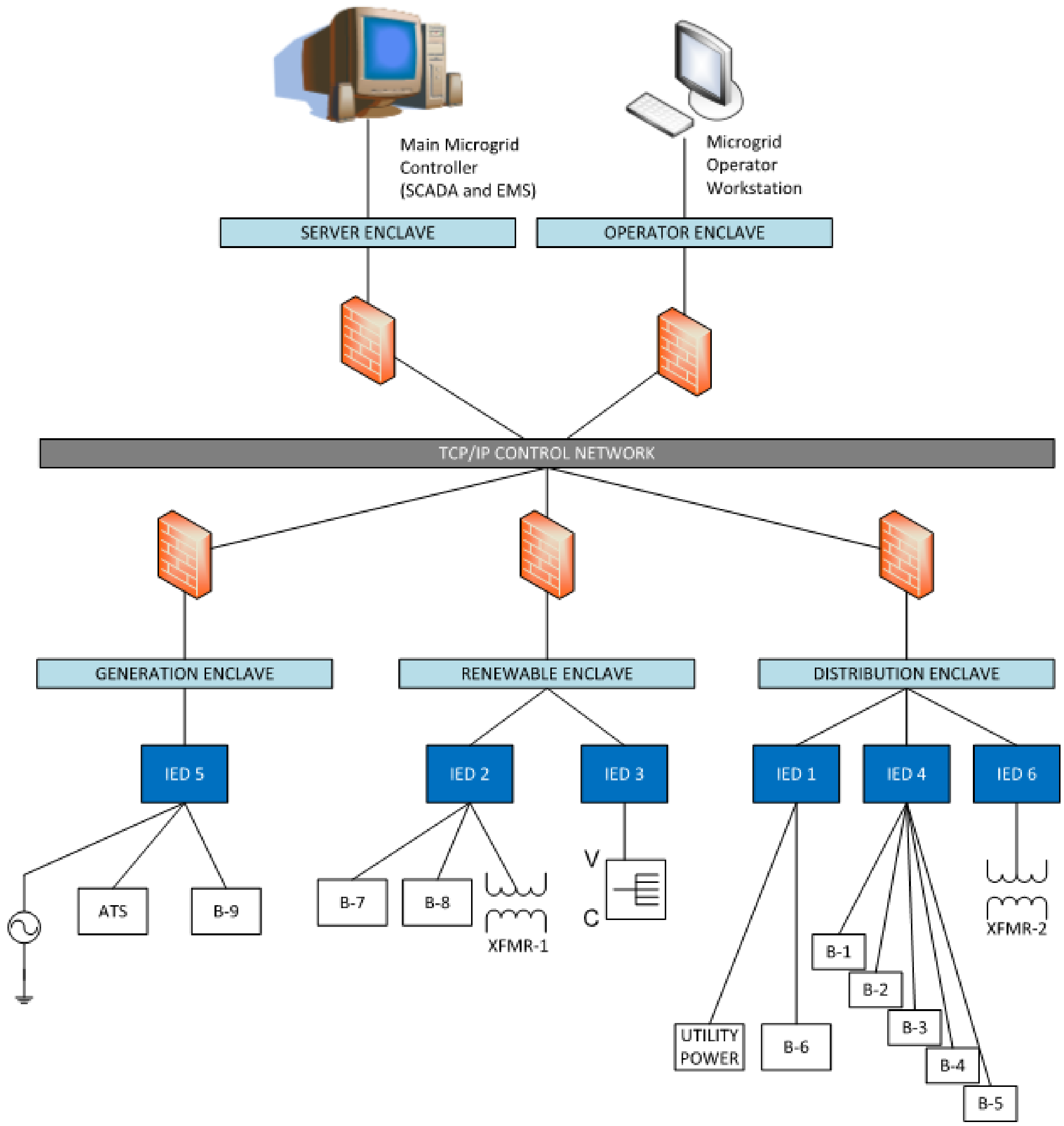
discrete or analog signals. Resulting data is processed by the IEDs connected to control elements.

- Automated Pad Mounted Equipment (PME) (Siemens 7SJ85 multi breaker control relay) – The PMEs, which include switches and fuses, are updated via remote control relay and are capable of controlling internal switches.
- Automatic Transfer Switch (Siemens 7SJ85 multi breaker control relay) – 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.
- Generation Controls (OEM CAT, Cummins, etc.) – These components are the primary resources for controlling 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.
- 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.

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

Figure 4. Diagram of Representative Microgrid Control System Hierarchy

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



2.7.2 Grid Parallel Mode Control

During grid parallel mode, generation assets will operate fully synchronized with the NYISO and Institute of Electrical and Electronics Engineers (IEEE) 1547 provisions for interconnecting distributed resources with electric power systems. Power generated either by the rotating sources (natural gas reciprocating engines) or inverter based energy sources (PV) will be synchronized with the main grid—that is, the AC voltage from DER assets will have the same frequency and phase as AC voltage from the main grid to ensure power quality and power delivery. The system will take the generation assets' output voltage reference from grid voltage using a phase-locked loop circuit. The phase-locked loop circuit, which is embedded in the generator controller, compares the voltage phase of each DER asset with the voltage phase of the grid and automatically adjusts generator frequency to keep the phases matched. The DERs will therefore operate in parallel with the main grid without causing voltage fluctuations at the point of common coupling greater than ±5%. The phase-locked loop circuit also allows the microgrid to operate as a virtual power plant if energy export is allowed. In this mode, all substations inside the electrical zone covered by the microgrid controllers will be in operation and will serve as the converting points from the transmission network to distribution.

During grid parallel mode, the solar PV system and natural gas generator will operate, fully synchronized with Con Ed's grid. If there is a failure or fault in Con Ed's grid, the microgrid will automatically switch to islanded mode.

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

2.7.3 Energy Management in Grid Parallel Mode

The proposed microgrid is designed to operate as an integrated system of software and hardware to ensure the highest levels of reliability and performance in all operating modes. This integrated system will filter information through the microgrid executive dashboard, which will include 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. In addition, the dashboard 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). All of these metrics include daily, weekly, and monthly rolling totals.

When the New Rochelle microgrid is connected to the Con Ed grid, the focus of operating the microgrid is to maximize the deployment of renewable generation and to manage local generation and curtailable loads to offset electrical demand charges.

2.7.4 Islanded Mode Control

The microgrid will switch to intentional islanding when there is a larger grid outage that would affect one or several feeders into the City of New Rochelle, leaving parts without power. The intentional islanding most likely will occur under the following circumstances:

- Con Ed grid has an expected outage which could potentially affect transmission power to New Rochelle substations.
- Con Ed grid needs to perform network maintenance work, thereby isolating loads in the New Rochelle area.
- Con Ed grid anticipates a certain level of hot pockets at the New Rochelle substations.

During the intentional islanding operation, the microgrid will receive the operator's command to prepare to enter island mode of operation. The microgrid 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 a seamless and closed transition (it does not require black start).

During a grid outage scenario at the Hebrew Center, the MCS will first disconnect the microgrid loads from the Cedar Street Substation feeds by opening the PME-9 connection to the ATS to fully isolate the area controlled by the microgrid system. All available generation will ramp up and be sequentially connected. At each step of the process for entering islanded mode, contingencies related to non-operational or non-responsive equipment will be considered, with appropriate actions specified.

During a grid outage scenario at Iona College, the MCS will disconnect the microgrid from the Twin Lakes Substation feed by opening new breakers located at each of the Iona loads' connection to the distribution line. The 1.6 MW generator and 300 kW solar PV will adjust output to match the three main loads. The medium voltage breakers/switches have been identified for remote control/monitoring upgrades to allow for the generator's sequential supply on startup and load shedding during microgrid operation. In order to maintain a stable system, the separate microgrid load areas will be supplied quickly and sequentially by the generator on startup through the existing, upgraded breakers located directly at the loads.

Once in islanded mode, the microgrid controls must maintain the voltage and frequency between acceptable limits and perform load following.

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

2.7.5 Energy Management in Islanded Mode

Once in islanded mode, the EMS will perform a series of operational tests to ensure the microgrid is operating as expected in a stable and reliable condition. Power flow, short circuit, voltage stability, and power system optimization studies will be performed using an N+1 (Component [N] plus at least one independent backup component) contingency strategy to determine whether additional load can be added. The N+1 strategy ensures that extra generation is always on line to handle the loss of the largest spinning generator and assumes the running generator with the highest capacity could go off line unexpectedly at any time. It should be noted that the shedding of low-priority loads may occur in order to maintain the N+1 power assurance.

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

- Generators that do not start
- Generators that trip off unexpectedly during microgrid operation
- Switchgear that fails to operate

- Switchgear that fails to report status
- Loss of power from the natural gas
- Loss of power from the solar

The EMS will optimize the New Rochelle microgrid function by managing storage, 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 New Rochelle'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 to 3 PM to 4 to 6 PM when grids tend to peak)
- Longer term storage: store energy from intermittent renewables for use later to firm up the supply to 24 hours or to improve/extend island mode operation

The results of the analysis indicated storage was not needed to resolve system reliability issues due to the flexibility in ramp rates of the other generators in the microgrid. The high cost of battery storage and the 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

It is envisioned that the natural gas generators at both the Hebrew Center and Iona College, along with the newest existing diesel generator at Iona College (MTU 4R0113DS125), be equipped with black-start capabilities. When the grid power goes out for New Rochelle, the microgrid controller initiates island mode by orchestrating the predefined black-start sequence. The microgrid then enters un-intentional 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. The microgrid controller waits a preset amount of time, approximately 30 seconds (in case Con Ed power comes back)
3. The microgrid controller EMS calculates expected load
4. The microgrid control system then automatically starts to synchronize generation by operating the breakers at the generation switchgears. After this, the system begins closing main switches across the distribution network to safely and sequentially configure the microgrid distribution system based on load priority order and available generation

The EMS will manage contingencies in case the breakers do not respond to trip commands and the Hebrew Center and Iona College do not properly isolate from Con Ed utility power. Contingency algorithms will handle the case in which one or more generators do not start as expected during a utility outage. If possible, the microgrid will still be formed but with only critical loads satisfied.

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

The microgrid will support on-site resources in a stable, sustainable, and reliable fashion. To ensure stability, the load and generation will be balanced continuously in real time. 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 also has the capability to utilize historical data and incorporate future estimates to predict peak loads and make recommendations to engineering and operations personnel. In addition, the microgrid can be designed and used to manage loads and resources for sustained cost savings.

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

2.7.7 Resynchronization to Con Ed Power

When power is restored to the larger grid, the main microgrid controller will coordinate a safe and orderly re-connection. The system will first wait a predefined, configurable time period to ensure that power has been reliably restored and then will commence resynchronization with the 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 the PCCs and determine when it is restored. When power is restored and stable for a predetermined amount of time (about 30 seconds to ensure the main grid is fully operational), the control system will synchronize and parallel the microgrid generation with the utility service through the utility circuit breakers. The PV systems will be disconnected. Before the microgrid system starts paralleling with the utility, it will balance the generation and load to not exceed minimum or maximum export limits and time durations set forth in the utility interconnection agreement. Once the feeders at Iona College are restored, generation breakers for diesel generators at Iona will trip automatically. The PCC's will be connected in re-synchronized mode. Consequently, the PV will be synchronized back to the grid automatically by inverters.

Please refer to New Rochelle 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 and telecommunication infrastructure in New Rochelle is best suited for a wireless microgrid communication system. The presence of this network is conducive to the addition of an automated microgrid, but it will still rely on several existing network switches in New Rochelle. The communication system and network switches (which have local backup batteries) will communicate wirelessly with the base station located at Hebrew Center building, which is electrically served by the microgrid in islanded mode. During the intermittent stage, or black-start sequence mode, the headend IT network equipment and base station for the IT network communications system will be powered by their backup batteries. The proposed design will use Con Ed's Wide Area Network (WAN) IT network for control and communication of the microgrid. The microgrid hardware will seamlessly integrate with their IT system using a minimal amount of additional hardware necessary to operate (i.e., the network switches, WiMax Base Station, WiMax subscriber units, servers, and computers required to manage a microgrid).

2.8.2 Existing IT & Telecommunications Infrastructure

New Rochelle 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 most desirable approach is for Con Ed to add a network switch at these facilities. If Con Ed is not able to add a switch as proposed, the microgrid could technically use either the Hebrew Center or Iona College's existing fiber-based IT network, but additional network configuration of the network routers would have to be achieved in order for all parties to communicate via a secure communication connection across the leased communication lines that are already in place.

The control system's wireless components, which work on open architecture protocols, use a TCP/IP Ethernet-enabled connection. This connection enables each of the uniquely addressed modules to wirelessly communicate via a standard, non-licensed radio frequency mesh 900 Megahertz (MHz) industrial scientific and medical (ISM) band signal network.

2.8.2 IT Infrastructure and Microgrid Integration

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 the 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 New Rochelle 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 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 will be utilized. If this is the case, more TCP ports will need to be active.

Activating and analyzing security logs is also 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. The team recommends implementing physical security at the perimeter of the control center building and network communication closets where the IT network 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 media access control (MAC) is an inexpensive and practical program that can help prevent unauthorized access and protect the New Rochelle network. Every network-attached device has a media access control 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 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 that these IEDs 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

This preliminary technical design portion of the overarching feasibility study has provided a solution based on a thorough examination of the existing utility infrastructure and energy demand requirements in order to conceptualize a real-time operation that is reliable and efficiently managed. The proposed design has incorporated industry best practices to increase resiliency to forces of nature and cyber threats, while also offering full automation and expandability at every level with its SOA-based framework for ease of interoperability.

In conclusion, the project is technically feasible. However, two significant items remain in order for New Rochelle's microgrid to become a reality. First, Iona College and the Hebrew Center must identify the specific locations for the proposed PV array and natural gas generators. In particular, Iona College has to finalize the locations for the generation assets to be located on their campus; however, the team believes at least ½ acre of the 43 acre campus should be available for the generation assets. Second, the generation assets and microgrid components must be available for maintenance at all times. The team is working with the facilities to develop the appropriate protocols and agreement structures to allow third parties to service the generation assets on their property. The Booz Allen team expects these operational and space challenges to be resolved by the time of construction.

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:

- Host organizations and the City will have sufficient interest in the DER assets to provide the necessary capital for the assets' construction. The Project Team has assumed host organization ownership of the generation assets, however neither organization has committed to that path at this time. Their ownership is not a prerequisite to successful implementation, however as campus-style clusters and the only direct off-takers in islanded operation the Team believes it is the most efficient.
- Con Ed or private investors could provide sufficient capital to fund the entire project, but Con Ed's domain expertise and involvement would be valuable contributions to the day-to-day operation of the microgrid. Absent Con Ed involvement, the Team would look to a competitive energy services provider such as Con Ed Solutions or Constellation to operate.
- The solar arrays will value electricity at the average commercial retail rate through net metering agreements with Con Ed.
- Con Ed will purchase electricity from the natural gas (NG) reciprocating generators at the utility's average supply price of electricity.[6]

The microgrid design will rely on DER owners to finance the construction of the natural gas reciprocating generators and solar arrays, which will be the primary generation resources at Iona College and the United Hebrew Complex. Preliminary analyses indicate selling electricity at Con Ed's average supply price may not generate sufficient cash flow to attract investor interest in the natural gas generators. This feasibility study does not consider the possibility of raising

[6] ~$0.073/kWh. Calculated as the average Market Supply Charge (MSC) from 2013-2015 plus the average MSC Adjustment for Con Ed's Westchester Zone. Data obtained from https://apps.Con Ed.com/CEMyAccount/csol/MSCcc.aspx and http://www.Con Ed.com/documents/elecPSC10/MSCAdjCurrentPSCNo10.pdf.

electricity sale prices because doing so would pass higher prices on to customers (without public funding or state incentives) and therefore contradict one of the project's central goals.

3.1 Commercial Viability – Customers (Sub Task 3.1)

The New Rochelle microgrid systems will include four facilities: Iona College, United Hebrew, Willow Towers Assisted Living (hereafter Willow Towers), and the Low-Savin Residence (hereafter Low-Savin). Ownership and operation will follow a hybrid ownership model wherein two separate SPVs own the proposed DERs and they, in conjunction with an owner/operator, will own the microgrid components/control infrastructure SPV. If Con Ed decides to serve as the owner/operator, the utility can provide helpful expertise in the day-to-day operation of the microgrid, while private investors and the host organizations will provide the majority of the capital outlay required for this project.

Iona College provides important services to the City during emergency situations, including shelter and food service capabilities. Three residential facilities comprise the United Hebrew Complex—although these facilities do not provide critical services, maintaining power to residences and life-saving equipment for geriatric citizens can be vital for their health and survival in emergency situations. Iona College owns ten diesel backup generators that will supplement the college's proposed DER assets, while the United Hebrew Complex will rely entirely on the proposed natural gas-fired reciprocating generator and solar array for its emergency power supply. Current backup generation at United Hebrew is disconnected for technical reasons; the Project Team hopes to include it in a Phase II engineering study.

3.1.1 Microgrid Customers

Two generators will provide power to Iona College: a 1.6 MW natural gas-fired reciprocating generator and a 300 kW solar array. The United Hebrew Complex will install a 1.5 MW natural gas-fired reciprocating generator and a 300 kW solar array. These assets will maintain power to their respective clusters during larger grid outages. The microgrids will disconnect from the larger grid (i.e., enter island mode) when they detect an outage or disturbance on the larger Con Ed system. The systems will also have the technical ability to enter island mode for economic reasons (to participate in Demand Response programs or provide cheaper electricity to customers when the spot market price is high), but they are unlikely to do so regularly.

Commands from the microgrid operator will catalyze automated sequences that will seamlessly disconnect the microgrids' DERs and loads from the larger grid. The true group of stakeholders that will benefit from the microgrid is discussed in Section 3.2.4. Table 12 below identifies each of the direct microgrid customers and the scenarios during which they will purchase services from the microgrid.

Table 12. Microgrid Customers

Table provides a list of facilities that will be connected to the microgrid. "IC Complex" refers to facilities that will connect to the Iona College microgrid; "UH Complex" refers to facilities that will connect to the United Hebrew Complex microgrid.

Property	Address	Classification	Critical Service	Back up Generation	Normal vs Island Mode
Iona College (IC Complex)	715 North Ave	School	Yes	Yes (Diesel)	Both
United Hebrew Geriatric Center (UH Complex)	391 Pelham Rd	Residential	No	No	Both
Willow Towers Assisted Living (UH Complex)	355 Pelham Rd	Residential	No	No	Both
Low-Savin Residence (UH Complex)	40 Willow Dr	Residential	No	No	Both

3.1.2 Benefits and Costs to Other Stakeholders

Prospective stakeholders in the New Rochelle microgrid extend beyond direct investors and facilities to include other Con Ed customers, existing generation asset owners, and residents of the areas surrounding New Rochelle. Direct benefits will accrue to the City, as an asset owner, other proposed DER asset owners, connected facilities, and the local utility. The surrounding communities and larger state of New York will enjoy indirect benefits from the microgrid (further discussed in section 3.2.4).

During an emergency power outage, the Iona College microgrid will maintain power to college facilities that are equally accessible and available to residents outside the City. In an emergency situation, this facility could provide shelter and basic life support (first aid, water, heat, etc.) to residents of the City and surrounding communities. The facilities at the United Hebrew Complex will provide similar services to residents, but they are not structured to shelter significantly larger populations.

Approximately 3.1 MW of natural gas-fired electricity and 600 kW of solar energy will provide load reduction for the larger Con Ed grid during both peak demand events and normal periods of operation. Future expansion of the microgrid could include the addition of a combined heat and power (CHP) unit to provide thermal energy to facilities, however no sufficient steam loads have been identified at this time.

Accounting for capital expense debt service, cash flows from the microgrid project will be consistently negative and will not recover the project's initial capital outlay. NY Prize Phase III funding will improve the financial outlook, however the project will still not generate sufficient cash flows to recoup the initial investment. If the entirety of the natural gas generation was available to receive DR payments from Con Ed, the project would have an additional value stream of approximately $300,000 per year. However, we do not anticipate the availability of DR payments for generators that are spinning at capacity at all times and shedding the loads of the microgrid via islanding is not likely to earn DR payments.

Peak load support from proposed generation assets will reduce congestion costs to NYISO, Con Ed, and electricity customers. While to-date Con Ed has maintained that there are no immediate congestion issues or infrastructure upgrade requirements in their Westchester service territory, load reduction on the system overall will result in decreased wear and tear on existing transmission and distribution infrastructure that may result in long-term savings to the utility. Finally, the utility will have the opportunity to design innovative rate structures and distinguish itself as a progressive supporter of the New York State Energy Plan. Lastly, local vendors, suppliers, and labor will be heavily contracted during the planning, design, construction, and operation phases of the microgrid project.

The negative effects and challenges directed towards stakeholders are relatively few. The primary costs will be purchasing and installing necessary microgrid equipment and proposed generation assets. However, significant challenges remain with respect to the Con Ed electrical footprint and the inability to reasonably include a more extensive and diverse mix of facilities.

3.1.3 Purchasing Relationship

A consortium will own the microgrid infrastructure, including potentially Con Ed as the owner/operator. Receiving suitable support from other investors, Con Ed could leverage its local domain expertise to operate and maintain the microgrid components and controls. The owners of the generation assets will sell natural gas-generated electricity to Con Ed under a buy back agreement or unique procurement model, while solar energy will be valued at the average commercial rate according to a net metering agreement.

Iona College and the United Hebrew Complex will need to develop two-way electricity provision relationships with Con Ed, as they will purchase services from the grid and Con Ed will purchase electricity from the on-site DERs. The volume of electricity purchased from the natural gas-fired reciprocating generators will depend on electricity output (dictated by microgrid controllers), system demand, and agreements between the owners and Con Ed. Depending on the local demand for electricity and baseline generator output, the reciprocating generators may 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 approximately 67% of each generator's maximum output, and it is cost inefficient to idle excess generation solely for ancillary services. It is unclear whether the generators could participate in NYISO ancillary service markets by aggregating their ramp-up capacity, but the minimum capacity would still represent around 33% of maximum output. 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. Solar energy produced by the proposed arrays will be sold to Con Ed under a net metering agreement.[7] Because the proposed microgrid customers do not

[7] This electricity is valued at the local commercial retail rate.

have significant demand for thermal energy, there will be no steam, hot water, or cool water transactions between DER owners and microgrid facilities.

DER owners will receive revenues from sales of electricity. Revenues will first be committed to covering operation costs and debt payments. Relevant SPV members will then receive a share of remaining cash flow that corresponds to their initial investment. Because host facilities will likely own majority shares in proposed DERs, the microgrid customers will benefit from electricity sales revenues as well as the enhanced reliability of energy supply.

3.1.4 Solicitation and Registration

The City and utility will work with identified facilities to join the project. This outreach will include informal discussions and, ultimately, signed agreements of participation in the microgrid and acceptance of the tariff or fee structure determined by the New York Public Service Commission (NYPSC). Formal registration with the microgrid will be managed by programming the logic controllers to include or exclude facilities 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 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 1.6 MW natural gas-fired reciprocating generator, a 1.5 MW natural gas-fired reciprocating generator, and two 300 kW solar PV arrays. Together these DERs will provide up to 3.7 MW of electricity for the microgrid and the wider community. Electricity sold into the Con Ed grid during parallel mode will not have a specific physical destination and power will be distributed to the macrogrid.

The current microgrid design does not include thermal energy output from proposed generators as there is insufficient thermal demand. If sufficient thermal energy demand develops, adding CHP capability to the proposed natural gas generators could add another revenue stream for asset owners.

Although the natural gas reciprocating generators will not have sufficient capacity available to participate in most NYISO ancillary services markets, the microgrid may be able to participate in the Con Ed DR programs by entering island mode during peak demand events. Entering island mode will take approximately 2.3 MW of load off the larger grid.[8] The New Rochelle microgrid

[8] 2.3 MW = average aggregate electricity demand in 2014 (data from Con Ed).

will be capable of entering island mode to participate in Con Ed DR programs. However, it is unclear whether this will qualify the microgrid for participation in Con Ed's programs. Operating the microgrid in island mode could theoretically reduce the load on the larger Con Ed grid by aggregating connected facilities' individual loads into a single point and removing them from the larger grid, but it also involves disconnecting local generation from the larger grid. Con Ed may therefore view the disconnection as a net-zero change in total load reduction.

3.2 Commercial Viability – Value Proposition (Sub Task 3.2)

The microgrid will provide value to New Rochelle, private investors, Con Ed, direct participants, and the State of New York. The proposed solar arrays and natural gas generators will reduce the City's reliance on higher-emission peaking assets and provide stable energy resources to critical and vital facilities in emergency situations. Electricity customers will benefit from a more stable power supply, and may see some price reductions from peak shaving.[9] DER owners will receive stable cash flows from the proposed energy generation resources and microgrid infrastructure owner(s) will receive 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 City of New Rochelle microgrid concept is structured as a hybrid ownership model wherein two separate SPVs own the distributed energy resource assets and microgrid infrastructure. Host facilities (i.e. Iona College and the United Hebrew Complex) will ideally purchase majority shares in the generation assets. Revenue streams from electricity sales (further described in Section 3.5.1) will accrue to creditors and investors. Utility ownership involvement in the infrastructure component is preferred because Con Ed has indicated they are not interested in allowing non-utility entities to operate any Con Ed infrastructure.

The hybrid model provides the greatest benefits and flexibility to the utility and customer base within the City, while allowing the utility to maintain full control of their lines and distribution infrastructure. As the entities best suited to developing and coordinating appropriate maintenance plans, host facilities will own majority shares in their respective DERs. As an entity with considerable domain expertise and existing infrastructure assets, Con Ed is an ideal candidate to operate new microgrid infrastructure. Finally, as a municipal entity with a good credit rating, New Rochelle can provide inexpensive capital to supplement the necessary initial capital expenditures for DERs and microgrid equipment. Because the City is not expected to own a majority share in any one SPV, it is exposed to relatively low risk. Table 13 below provides an overview of New Rochelle microgrid project, including an analysis of project strengths, weaknesses, opportunities, and threats (SWOT).

[9] Electricity in New Rochelle is expensive. The residential and industrial rates are 32% and 58% greater than the NYS averages, respectively (http://www.electricitylocal.com/states/new-york/new-rochelle/). The area is therefore an ideal target for peak shaving.

Table 13. New Rochelle Microgrid SWOT

Table includes the Strengths, Weaknesses, Opportunities, and Threats (SWOT) of the project.

Strengths	Weaknesses
• Disaggregates the 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 • Aligns interests of the City (and therefore community), Con Ed, connected facilities, and private investors in seeing the microgrid succeed • Leverages Con Ed expertise to facilitate load aggregation, load following, voltage regulation, and other necessary daily operations • 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 DER owners and Con Ed are required to ensure value for DER investors, but they may negatively impact utility credit ratings • Backup generators at Iona College are isolated from the United Hebrew loads • Utilities may only own generation assets under exceptional circumstances; the project therefore needs to separate ownership of generation assets from ownership of microgrid components • The Con Ed electrical system limits the proposed footprint as well as future expansion possibilities
Opportunities	**Threats**
• Serves as a replicable template (most NY communities are served by investor-owned utilities (IOUs)) and encourages coordination between local government, private investors, and utility • Experiments with new methods of rate calculation, with the opportunity to advance the role of utilities in electricity generation, distribution, and consumption in New York State • Demonstrates the feasibility of reducing load on the larger grid and provides data to target critical congestion points on the larger grid for future projects • Expanding microgrid to include facilities with thermal loads—adding a CHP would produce revenues for the DER owners from incentives and steam sales • Provides 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 reveal a larger opportunity for microgrid development in New York State	• Changes in regulatory requirements could impact the proposed business model and stakeholder goals • If natural gas prices increase, it will significantly raise the microgrid's marginal cost of producing electricity, which may prompt a re-negotiation of Con Ed's purchasing price • The Federal Business Investment Tax Credit (ITC), which could recover up to 30% of the cost of the two solar arrays, may expire at the end of 2016 • Without Phase III NYSERDA funding, the project cannot cover its capital expenditures

While there are several valuable strengths and opportunities associated with the hybrid ownership model, there are also weaknesses and threats that must be addressed. These weaknesses are discussed below:

- **Financial** – DER owners will seek a long-term PPA, or some other form of long-term off-take agreement, with Con Ed to guarantee steady future revenue streams. As long as the agreement reliably guarantees fair compensation for generator output over the project lifespan, DER owners must be content with flexible compensation rates and low levels 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. Some of this weakness is offset by NY Prize Phase III funding. The aggregate peak demand from the United Hebrew Complex was approximately 1.5 MW in 2014. With a reliable 1.5 MW of capacity from the natural gas generator and a potential 300 kW of capacity from the solar array, the proposed electricity supply should be sufficient for the energy needs of the complex. However, as the United Hebrew Complex's electricity demand grows in future years, the facilities may have to invest in backup generators, small-scale demand response programs, or energy efficiency upgrades.
- **Organizational Burden** – The hybrid model requires collaboration among groups of stakeholders that may have different motivations. In the context of this business model, in which electricity generation will be sold at all times to Con Ed via a PPA, this is unlikely. However if the model develops into a load following regime, this could become problematic.
- **Regulatory** – The structure proposed in this document complies with existing policies and regulations, however, changes in New York Public Service Commission (PSC) PSL §§ 2(2-d) could support a business model that is economically more advantageous and in line with the intent of NY Prize and the NYSERDA effort to develop community microgrids. That policy change should include working with the Federal Energy Regulatory Commission (FERC) and PSC to include community microgrids as eligible for qualifying facility designation and, absent Federal action, promoting the development of primarily natural-gas fired community microgrids under existing PSC authorities. It would be further advantageous if the policy adjustments for microgrids would allow a larger number of facilities to be served than under the current test.

3.2.2 New Technology

Minimal need for technology and infrastructure investments strengthen the New Rochelle microgrid's commercial viability. However, the microgrid design includes a SCADA-based control system that allows remote monitoring and control of islanding and generator output. In the future, the microgrid could be expanded to include commercial, local government, and health facilities by moving switches, installing new lines, or installing AMI in the City.

Smart meter technology is advancing rapidly and may 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.

3.2.3 Replicability and Scalability

The two clusters of the New Rochelle microgrid are largely replicable and scalable models and are being designed with industry standard equipment and software that can be applied to diverse existing infrastructure. However, it is less preferable to have physically and electrically discrete clusters of facilities; this would represent only an expansion of campus-style grids.

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 cities would have to sacrifice the reliability (by relying on solar or wind power) or emissions efficiency (by using diesel or fuel oil) that make this project feasible.

Organizational Replicability. The proposed business model does not present a barrier to project replicability, but the lack of thermal demand and consequent reliance on NYSERDA NY Prize Phase III funding for commercial viability limits the specific replicability of a microgrid that only sells electricity.

The proposed generation assets qualify for a relatively small total incentive payment—the Federal Business Incentive Tax Credit (ITC) will recover around 30% of installed capital costs for the solar arrays, but the natural gas reciprocating generators are 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. As discussed above, leveraging Con Ed DR programs is unlikely. This hinders the project's replicability.

Scalability. The microgrid is scalable to the limits of the network architecture of surrounding power lines and the existing generation assets. However, given that it fundamentally consists of two campus-style microgrids operated by a single set of controls, it is not desirable to scale this model, and it would become operationally difficult as multiple, new campuses were added.

3.2.4 Benefits, Costs, and Value

The microgrid will provide widely distributed benefits, both direct and indirect, to a multitude of stakeholders. DER owners will receive stable cash flows for many years to come, the City and citizens will benefit from a more resilient electricity system, customers will see lower electricity prices (from reduced demand when prices on the spot market are high), and the community will reap the positive effects of living in and around the microgrid. However, without funding from NY Prize Phase III, the cash flows generated by proposed DERs will not fully recover initial investments. Projected costs and benefits are discussed in Tables 14 through 19.

The customers will bear only the costs of ownership of the generation assets, a small tariff paid to the microgrid controllers to provide load following, disconnect, and islanded operations service, and marginally increased power prices during an outage on the grid. The local community will not bear any of the project's costs. This proposal involves a wide group of stakeholders—from local, non-customer residents to the State of New York—and provides value to all involved parties.

The exhibits below provide an overview of the benefits and costs to members of the SPVs, direct microgrid customers, citizens of New Rochelle and surrounding municipalities, and the State of New York.

Table 14. Benefits, Costs, and Value Proposition to DER Owners

Table describes the benefits, costs, and value proposition to DER owners.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Distributed Energy Resource Owners	- Investors will receive annual cash flows from solar array net metering and electricity sales from the NG reciprocating generator - Federal ITC recovers 30% of solar array's cost in the project's first year (for private investors; the City is not eligible for this tax credit) - Entering island mode during peak demand events could qualify the microgrid for lucrative Con Ed DR programs. However, Con Ed is unlikely to accept "islanding" as eligible load reduction - NY Prize Phase III funding could recover up to $5 MM of initial project costs	- Initial capital outlay will be significant, as each SPV must purchase and install its generation assets - Forecasted installed capital costs for solar array and NG reciprocating engine are ~$525,000 and ~$2 MM, respectively[10] - Ongoing maintenance of DERs - Financing costs associated with initial capital outlay will persist for many years	- Baseline operation of NG generator and solar array provide positive cash streams for many years. These cash flows may be supplemented by strategic participation in demand response programs and/or ancillary services markets - Federal ITC will recover up to 30% of installed cost for each solar array's private investors - Inclusion in the microgrid should provide generation asset owners with a reliable energy market

[10] NG reciprocating engine: $1,300 per kW (estimate from Siemens), Solar Array: $1,750 per kW (pro-rated from Siemens 2 MW estimate).

Table 15. Benefits, Costs, and Value Proposition to Consolidated Edison, Inc.

Table describes the benefits, costs, and value proposition to Con Ed.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Con Ed (as majority shareholder in microgrid infrastructure)	- The utility will receive revenue from T&D charges and microgrid tariffs that support the construction and operation of the microgrid - The utility will continue to sell electricity to direct customers - The utility will avoid 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; this may defer future Transmission & Distribution investments	- Private and municipal investors will provide capital outlay for infrastructure, such as switches and cutouts - As the majority owner of microgrid infrastructure, Con Ed will be responsible for operating the microgrid on a day-to-day basis - The utility may be responsible for paying buy-back tariffs to generation assets that do not qualify for net metering. Costs would be recouped through sales to existing Con Ed customers	- The utility can serve as a market connector without the costs associated with constructing and operating distributed energy resource assets - Con Ed will have a new supply of electricity that is valued at their average supply charge, but will have a slightly reduced transmission and distribution costs in the area

Table 16. Benefits, Costs, and Value Proposition to the City of New Rochelle

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
New Rochelle (as local government)	- The microgrid will provide a resilient and redundant energy supply to critical services - Meet NY state energy goals by encouraging DER construction and improving energy resiliency - In the future, municipal government facilities could be included in one of the clusters - 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 vital services will keep the lights on during outages, allowing the City of New Rochelle to be an oasis of relief for local citizens and surrounding areas - 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

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Connected Facilities	- Resilient and redundant energy supply to operations—outages cost commercial and residential customers ~$40-60/kWh and ~$5-8/kWh, respectively[11] - Addition of CHP capability could provide thermal energy to connected facilities in the future - 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 New Rochelle community - Potential for partnerships and a local market for excess generation will encourage industrial stakeholders to build large-scale generation assets - Local market for excess energy makes investments in small DERs (such as solar panels) profitable for connected facilities

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Community at Large	- Access to a wide range of critical and vital services during grid outages - Potential for rate decreases in the future as DER owners realize continued revenues beyond the period of bond payment	- 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 and vital loads - Future expansion of the microgrid could bring more facilities into the design—however, the City of New Rochelle will likely need to install widespread advanced metering infrastructure to make this feasible

[11] PG&E; cited from http://www3.epa.gov/chp/basic/benefits.html.

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

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

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

3.2.5 Demonstration of State Policy

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 low-cost 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 EE programs and increasing generator output during peak demand events, the New Rochelle 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. However, we believe there is an opportunity for NYSERDA to work with the NY PSC to help provide clarity to the DSPs as to providing demand response programs specific to community microgrids that will monetize the value of reducing system-level congestion at peak times.

The microgrid presents an excellent opportunity to further expand future renewable energy generation and immediately improve the City's resiliency to extreme weather events. Paired with energy efficiency programs, generation assets in New Rochelle could shave a substantial electricity load from the larger grid during peak demand events when congestion costs are highest.

Additionally, the microgrid will provide a local market for excess electricity generated by distributed renewable generation assets, greatly improve the resiliency and reliability of local energy supply in extreme weather situations, and encourage citizens within the community to invest in local energy generation and distribution. New Rochelle's microgrid and DER assets will immediately reduce the City's reliance on higher emission peaking assets during peak demand events and provide a platform for expanding the town's clean DER capability in the future.

3.3 Commercial Viability – Project Team (Sub Task 3.3)

The Project Team includes Con Ed, the local New Rochelle government, Booz Allen Hamilton, Siemens AG, and Power Analytics. It may expand to include financiers and legal advisors 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 and in constant communication with local stakeholders from the outset. Booz Allen and its partners in the City 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 New Rochelle microgrid project is a collaboration between the public sector, led by the City of New Rochelle, and the private sector, led by Booz Allen Hamilton and Consolidated Edison with significant support from Power Analytics and Siemens. Local partners Sustainable Westchester and Pace further contributed to the Phase I project development. Each of the private sector partners is exceptionally well qualified in the energy and project management space, and the City of New Rochelle has strong interest in improving its energy reliability and expanding its clean energy generation capacity. Tables 20 and 21 describe in more detail the Project Team and roles at each stage of the project life cycle.

Table 20. 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. 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 is now 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 Edison 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 Edison receives yearly operating revenues of approximately $13 BN and owns assets totaling approximately $44 BN.</td></tr>
</table>

Table 21. Project Team Roles and Responsibilities

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

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
Consolidated Edison, Inc.	Con Ed could serve as partial owner of the microgrid infrastructure. The utility's expertise will be essential in planning microgrid construction, and the utility should commit to ongoing operation and maintenance of the microgrid.	Con Ed will provide a share of the initial capital outlay that corresponds to its ownership share of the SPV.	Con Edison will provide the necessary domain expertise to operate and maintain the microgrid. This includes responsibility for switching to island mode and regulating voltage and frequency across the microgrid's loads in both grid-connected and island mode.
City of New Rochelle	The City may elect to control minority shares in any of the SPVs (DERs or microgrid infrastructure). It will serve as the main conduit to representatives of the critical and vital facilities and other interests in the City. This effort is spearheaded by the City Mayor, who is responsible for local outreach.	As the liaison, the City will coordinate with all local and state parties as needed. The City will also provide a share of the capital outlay that corresponds to its ownership of the SPV or SPVs.	As the liaison, the City will coordinate with all local, regional, and state parties as required. The City will also provide a share of necessary services and capital to maintain the microgrid that correspond with its ownership share of the infrastructure 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.

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
Power Analytics	Power Analytics is the partner for energy software solutions. The PA team, in conjunction with Siemens and Booz Allen, is responsible for the design of the SCADA and system software components and controls.	Power Analytics may lead the installation of control and energy management software following hardware installation and in concert with Siemens.	Provide IT systems support; may play an active role in system management through the EnergyNet software platform.
Suppliers	There are no suppliers required during this development phase, however project partners and suppliers Siemens and Power Analytics are closely involved in feasibility and design portions of the project. BAH is in touch with several additional suppliers of hardware and software including Duke Energy, Con Ed Solutions, Enel Green Power, Anbaric Transmission, Bloom, and Energize.	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 require 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 New Rochelle bond offering and creation of the Special Purpose Vehicles. The SPVs 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 City, Con Ed, and any investor counsel required.	Legal and regulatory will be the responsibility of the City, the utility, and any investors in the Special Purpose Vehicle.

3.3.3 Financial Strength

The principal shareholders in the microgrid project are the DER owners (private investors), New Rochelle, and Con Ed. Private investors that do not publish financial statements are not discussed in this section.

In March 2015, Moody's Investor Service assigned Iona College's proposed $44 million of fixed rated Series 2015 A&B Revenue Bonds (to mature in FY 2045) a long-term credit rating of Baa2. Obligations rated as Baa are "judged to be medium-grade and subject to moderate credit risk and as such may possess certain speculative characteristics." The College currently possesses total assets worth approximately $233 million and long-term debt of approximately $75 million (pending issuance of the $44 million of fixed A&B revenue bonds). As such it may be unwilling to finance DERs by raising more long-term debt. However, the College had a cash base of around $9 million and posted $18 million of net cash flow from operating activities in 2014—with this level of liquidity, the College is capable of financing its share of the proposed DERs with short-term debt or pure equity.

Moody's Investor Service gives the City of New Rochelle's $5 million general obligation bonds a long-term credit rating of Aa3 (its fourth highest ranking) and has published a positive opinion on the City's future credit outlook. The rating extends to $69.1 million of debt, which is well over the City's expected capital outlay for the microgrid project. An obligation rated as "Aa" indicates that "obligations…are judged to be of high quality and are subject to very low credit risk". Moody's credit rating reflects the city's large tax base, above-average wealth levels, adequate reserve position, and low debt burden. The City will therefore qualify for relatively low interest rates should it choose to finance the microgrid project with debt.

Moody's 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 billion and receives annual revenues of approximately $13 billion. Revenues have been consistent for years, and Con Edison recently posted an increase in dividends per share for FY 2014.

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 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.

Solar PV arrays and natural gas-fired reciprocating generators were chosen as generator technologies to reduce GHG emissions and enhance the reliability of the power supply. The NG units 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. They 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 New Rochelle, but thermal demand is limited. Installation of any significant CHP unit is cost prohibitive until facilities with more thermal demand connect to the microgrid.

The solar PV units will provide a renewable component to the microgrid generation mix and represent more appropriate additions than expanded NG units. They will provide emission-free electricity during daylight hours and move New Rochelle and New York State closer to the renewable generation goals set forth in the New York State Energy Plan. PV generation will face the same problems in New Rochelle that it does elsewhere in the northeast United States: variable weather conditions and long periods of darkness in the winter.

The New Rochelle microgrid includes numerous components that have been previously used and validated. Solar PV and reciprocating natural gas generators are both widely used technologies, with more than 6 gigawatts of solar PV installed in 2015 in the United States. In July of 2015, New York State produced a net 6,000 gigawatt hours of natural gas-fired electricity[12]. 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.[13]

3.4.2 Operation

All investors in the microgrid infrastructure SPV will contribute funds to operate and maintain the grid, but Con Ed will oversee most of the logistics associated with day-to-day operation. A critical mass of registrations is required to ensure that the microgrid's electricity service purchasers are receiving the best value. Critical mass will be achieved with the registration of the

[12] EIA: http://www.eia.gov/state/?sid=NY#tabs-4.

[13] Siemens case studies; available from http://w3.usa.siemens.com/smartgrid/us/en/microgrid/pages/microgrids.aspx.

identified customers and will not need to expand to further facilities. The microgrid is a classic shared value entity; the utility, City, and customers will benefit financially, and the continued success of the grid requires support and collaboration from all three.

As the majority owner in the microgrid infrastructure SPV, the owner/operator 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, 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 infrastructure 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 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 within the local Con Ed grid. The facilities will continue to be billed for electricity via the regular Con Ed billing mechanism and cycle. Con Ed's revenue should 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 rate tariff.

3.4.3 Barriers to Completion

The barriers to constructing and operating the microgrid are largely financial: the project cannot stand alone as it cannot recoup the capital investment required. 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 minor participation in demand response programs. Assuming the DERs will sell electricity to Con Ed at their current supply charge, the microgrid will cover variable operations costs. 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. That is, the project is net negative and cannot cover debt service. The New Rochelle microgrid qualifies for relatively few of the available state and federal incentives for DERs—the Federal ITC will offset 30% of the capital cost of the solar array for private investors, but this only amounts to 4-5% of total project cost. As such it must rely on direct project-generated revenues and NY Prize Phase III funding to achieve commercial viability.

The second major barrier is physical constraints. The feeder networks in the vicinity of the two clusters do not allow for the addition of further critical facilities at this time. This is a negative in the view of NYSERDA, however the infrastructural realities of the Con Ed system dictate the currently included facilities. Further, there is limited space available for large scale generation at either location, and while the Project Team believes that the proposed generation could be scaled up, space limitations and surrounding density are real concerns.

3.4.4 Permitting

The New Rochelle microgrid may require certain permits and permissions depending on the ultimate design choices. Distributed energy resource assets will require zoning variances, as they will be placed on Residential and Hospital land. New Rochelle 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 under net metering and buy-back tariff (or other custom procurement model) agreements. These assets will require significant initial capital outlay as well as annual operation and maintenance (O&M) costs. Private investors in the solar arrays qualify for the Federal ITC, which will partially offset the initial investment costs. The City of New Rochelle may issue municipal revenue bonds to finance its relatively minor share in proposed DERs and microgrid infrastructure. While most private investors may leverage a mix of long-term debt and equity to finance their shares in the project, Iona College will likely choose a financing strategy that minimizes long-term debt. This section will discuss the revenues, costs, and financing options associated with the microgrid project in more detail.

3.5.1 Revenue, Cost, and Profitability

The microgrid has a number of savings and revenue streams, as outlined in Table 22. The revenues will sum to approximately $1.83 million per year, which will exceed the yearly generation costs (estimated to be around $1.57 million per year). Capital expenditures for microgrid equipment and DERs, as described in Section 4.4.1, will sum to approximately $6.2 million with new overhead lines. Planning and design operations will cost approximately $1 million, but will be recouped by 75% NY Prize Phase II funding with a 25% cost share.[14] The commercial viability of the New Rochelle microgrid project depends heavily on Phase III NY Prize funding. See Table 23 for the capital and operating costs.

[14] Estimates developed by Booz Allen.

Table 22. Savings and Revenues

Table describes expected revenues and savings directly associated with operation of the microgrid and its DERs.

Description of Savings and Revenues	Savings or Revenue	Relative Magnitude	Fixed or variable
Electricity sales from 1.6 MW natural gas-fired reciprocating generator during grid connected mode[15]	Revenue	~$870,000/yr	Variable
Electricity sales from 1.5 MW natural gas-fired reciprocating generator during grid connected mode	Revenue	~$810,000/yr	Variable
Electricity sales from 300 kW solar PV array (Net Metering) during G-C mode	Revenue	~$75,000/yr	Variable
Electricity sales from 300 kW solar PV array (Net Metering) during G-C mode	Revenue	~$75,000/yr	Variable
Electricity sales to customers during islanded operation	Revenue	~$1,500/yr	Variable
Total Revenue		**$1.83 MM/yr**	Variable

[15] 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.

Table 23. Capital and Operating Costs

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

Description of Costs	Type of Cost	Relative Magnitude	Fixed or Variable
1.6 MW NG Recip. Generator	Capital	~$2,100,000	Fixed
1.5 MW NG Recip. Generator	Capital	~$1,950,000	Fixed
300 kW Solar PV array	Capital	~$525,000	Fixed
300 kW Solar PV array	Capital	~$525,000	Fixed
Microgrid Control Systems	Capital	~$100,000	Fixed
Distributed Equipment	Capital	~$140,000	Fixed
IT Equipment (Wireless stations and cabling)	Capital	~$90,000	Fixed
New distribution lines and man holes	Capital	$740,000 (overhead) $2.84 MM (underground)	Fixed
Total CapEx		**$6.2 MM** (overhead wires)	Fixed
Design considerations and simulation analysis	Planning and Design	$750,000	Fixed
Project valuation and investment planning	Planning and Design	$100,000	Fixed
Assessment of regulatory, legal, and financial viability	Planning and Design	$75,000	Fixed
Development of contractual relationships	Planning and Design	$75,000	Fixed
Total Planning and Design		**$1,000,000**	Fixed
1.6 MW NG Generator Fuel	Operating	~$610,000/yr	Variable
1.5 MW NG Generator Fuel	Operating	~$560,000/yr	Variable
1.6 MW NG Generator Maintenance	Operating	~$165,000/yr	Variable
1.5 MW NG Generator Maintenance	Operating	~$155,000/yr	Variable
Solar PV Maintenance	Operating	~$6,000/yr	Variable
Solar PV Maintenance	Operating	~$6,000/yr	Variable
Total OpEx		**$1.54 MM/yr**	Variable

The proposed microgrid will qualify for only one existing incentive program: the Federal ITC, which is currently set to expire in 2016, before the conclusion of NY Prize. The program will recover 30% of the solar array's capital cost for private investors. Other possible sources of incentive revenue include NYSERDA Phase III NY Prize funding (up to $5 million, but will not exceed 50% of total capital costs), NYSERDA Phase II funding (up to $1 MM for design and planning costs) and capacity payments for participation in Con Ed DR programs. Without these, the project is not economically viable. The New Rochelle microgrid will have the technical ability to enter island mode to participate in DR programs, but as 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 and islanding would remove both loads and generation from Con

Ed, yielding a net neutral change in demand to the Con Ed system. Available incentive programs are detailed in Table 24.

Table 24. Available Incentive Programs

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

Incentive Program	Value	Required or Preferred
NYSERDA NY Prize Phase II	Up to $1,000,000	Required
NYSERDA NY Prize Phase III	Up to $5,000,000	Required
Federal ITC	~$315,000	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 all shareholders providing capital for any costs that exceed available NYSERDA funding. New Rochelle 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 various investors will leverage Phase III funding from NYSERDA to complete the construction phase and will supplement with capital from municipal bonds, long-term debt, and private equity. Phase III NY Prize funding, which will provide up to $5 million in cost sharing for microgrid and DER equipment purchase and installation, will cover around 50% of the capital costs.[16]

The City of New Rochelle is willing to issue municipal bonds to finance their relatively minor share in the project. 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 City'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. Financing obligations will depend on the City's share in the various DERs and

[16] Total capital costs are $6.2 MM including overhead lines and $8.3 MM including underground lines.

infrastructure, the amount of NYSERDA NY Prize funding received, and the magnitude of future operation and maintenance costs. Specific market conditions at the time of issuance will determine interest rate and repayment schedule.

The infrastructure SPV will lease needed land from the City of New Rochelle, Iona College, or the United Hebrew Complex for the purpose of constructing microgrid infrastructure. Proposed DERs will be located at Iona College and on land owned by the United Hebrew Complex—to avoid complications it will therefore be ideal for the college and the United Hebrew Complex to own majority shares in their respective assets.

The operational phase will be characterized by positive revenue streams. Structured as a typical infrastructure project, the microgrid revenue model will be built for a 20 year period (mirroring the expected lifespan of microgrid infrastructure and generation assets). The project is not expected to generate sufficient cash flows to cover debt service payments in the absence of NY Prize Phase III.

3.6 Legal Viability (Sub Task 3.6)

Like any infrastructure project that involves development of public and private land, the New Rochelle 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. Private investors will own and operate the DERs, while the utility will own and operate microgrid infrastructure. This will avoid the investment and regulatory burden normally associated with private power distribution as well as the potential legal complications that could arise from utility ownership of DERs. Microgrid equipment will be installed on city-owned land, while generators will be installed at Iona College and United Hebrew Geriatric Center. Property rights and access limitations will not be a concern for microgrid infrastructure, but DER owners will need to address these issues for proposed generators. Con Ed, Iona College, the United Hebrew Complex, and any other private DER investors will need to develop trilateral operating agreements for the DERs located at Iona College and the United Hebrew Complex (Solar PV array and NG-fired reciprocating generator for each). The data network that supports the microgrid logic units and controllers is owned by the City of New Rochelle—access to this network will not represent a significant barrier to project completion.

3.6.2 Regulatory Considerations

State and Utility Regulation

If Con Ed choses to own the infrastructure associated with the microgrid, it will qualify as the electric distribution company for the project. DER owners will sell goods to Con Ed as private entities (and will be regulated as such). New models of regulatory treatment (currently under discussion in REV proceedings) may also apply, if adopted.

The PSC will continue to treat Con Ed as an electric corporation, and the SPV that owns microgrid infrastructure is unlikely to be exempted from this regulation as it does not meet the criteria for a "qualifying facility" under the terms of PSL §2. The microgrid owners may petition the PSC for a declaratory ruling that the proposed users (connected facilities) do not run counter to the PSC's interpretation of PSL §2, however the Project Team anticipates an unfavorable resolution of the petition. A petition for lightened regulation may be the most advantageous path forward.

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.[17] "Use" encompasses occupying public rights-of-way and operation of the provider's built infrastructure to provide the public service.[18]

Iona College is zoned as a Two Family Residence District (R2-7.0) and the United Hebrew Complex cluster is zoned as a Hospital District (H). Electric generation is not permitted in either of these districts, and as such must be approved either as an accessory use, under a special permit for public utility uses, or as a variance. The proposed generators will not qualify as "accessory" generators, so DER owners will likely need to seek variances from the Zoning Board of Appeals.

Absent a zoning variance, there is a third path forward. If electric generation for were added as a specially permitted use in each of the districts in which microgrid customers have been proposed, it would create a regulatory path forward while allowing the Zoning Board of Appeals to maintain some essential controls over the character and uses of affected neighborhoods.

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

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[17] N.Y. Vil. Law § 4-412.

[18] 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).

is delivered to the grid versus used onsite, and the date of construction. The specific details associated with the proposed reciprocating generator in New Rochelle 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), and 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 Finacial Viability Conclusions

The microgrid project will include one critical facility and three important residential facilities from the New Rochelle (Iona College, United Hebrew Geriatric Center, Willow Towers Assisted Living, and the Low-Savin Residence). Ownership will follow a hybrid model wherein private investors own proposed DERs and the system's operator will own the in microgrid infrastructure. The City may purchase minority shares in any and all of the SPVs. This ownership structure will give the project owners access to cheap capital (through the City's ability to issue municipal revenue bonds) and significant domain expertise (through Con Ed's knowledge and experience with electricity distribution in the area). Hybrid ownership avoids legal complications resulting from utility ownership of DERs or private ownership of distribution infrastructure and coordinates shareholder interests by linking ROI to the success of other SPVs.

The proposed microgrid's commercial feasibility depends on NY Prize Phase III funding. Its design includes two new DERs to be located at Iona College (a 1.6 MW natural gas fired reciprocating generator and a 300 kW solar PV array) and two new DERs to be located at the United Hebrew Complex (a 1.5 MW natural gas fired reciprocating generator and a 300 kW solar PV array). Iona College and the United Hebrew Complex will ideally provide the capital required to purchase and install these generators, and will receive revenues from electricity sales to Con Ed throughout the generators' lifespan—however, if the College and the United Hebrew Complex are unwilling to purchase shares in the generators, other private investors may do so. The Project Team forecasts yearly aggregate revenue of approximately $1,830,000 from the generators, which should reliably cover yearly generator operation and maintenance costs (forecasted to be approximately $1,530,000 per year) and will be earned directly by the controlling SPV. The generators will produce positive annual net incomes, but will require subsidies to fully recover initial investment costs (after discounting future cash flows).

In addition to revenues from electricity sales, the microgrid will provide indirect financial and non-financial benefits to New Rochelle citizens, SPV shareholders, Con Ed, and the 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 New Rochelle and reveal a larger market for thermal energy—adding CHP capability to the proposed reciprocating generators would improve their efficiency and add new revenue streams to the owners' portfolios.

Permitting and regulatory challenges should be reasonably straightforward, although Iona College and the United Hebrew Complex (or other private investors) will need to seek zoning variances in order to install the reciprocating generators and solar PV arrays. The primary regulatory consideration will be the Clean Air Act permitting of the new reciprocating generators.

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 of proposed generators. Similarly, if Con Ed serves as the operator, the utility will facilitate smooth day-to-day operation of the microgrid and its control infrastructure by purchasing a majority share in microgrid infrastructure. Second, the solar array will sell electricity at the average local commercial retail rate through a Net Metering Agreement with Con Ed. Con Ed will purchase electricity generated by the reciprocating generators at the utility's average supply price of electricity. Lastly, this proposal assumes a Phase III NY Prize award as it is an absolute requirement for financially tolerable project.

4. Cost Benefit Analysis

The Cost Benefit Analysis section is made up of seven sections in addition to the introduction:

- ***Section 1*** analyzes the *facilities connected to the microgrid* and their energy needs.

- ***Section 2*** discusses the *attributes of existing and proposed distributed energy resources*, including factors such as nameplate capacity and expected annual energy production.
- ***Section 3***, analyzes *potential ancillary services sales and the value of deferring transmission capacity investments*.
- ***Section 4*** reviews the *overall costs* associated with construction and installation of the microgrid as well as the fuel, operation, and maintenance costs required over the lifetime of the microgrid.
- ***Sections 5 and 6*** discuss the *community benefits* of maintaining power during a grid-wide outage and outline the costs associated with operating the microgrid in island mode.
- ***Section** 7* presents the Industrial Economics (IEc) *benefit-cost analysis report and associated Project Team commentary.*

4.1 Facility and Customer Description (Sub Task 4.1)

The New Rochelle microgrid will include four facilities from various rate classes and economic sectors. NYSERDA designates three primary rate classes based on type of facility and average electricity consumption: residential, small commercial (less than 50 MWh/year), and large commercial (greater than 50 MWh/year). All four proposed microgrid facilities belong to the large commercial rate class, requiring approximately 11,800 MWh of electricity per year. The microgrid facilities fall into two economic sectors: education and residential. Iona College falls into the education sector and all other facilities fall into the residential sector. See Tables 25 and 26 for basic statistics on each facility's energy usage.

The generation assets included in the microgrid design will be capable of meeting 100% of the average aggregate facility energy usage during a major power outage, but they will approach their generation limits if the facilities reach peak energy use any without load reduction. In these situations at Iona College, the diesel generators may need to come online to supply additional electricity to the campus.

Table 25. Facility and Customer Detail Benefit – Iona College[19]

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

REDACTED PER NDA WITH CONSOLIDATED EDISON

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

Table 26. Facility and Customer Detail Benefit – United Hebrew[20]

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 CONSOLIDATED EDISON

[20] 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 two new natural gas generators, two new solar PV arrays, and ten existing diesel generators. The proposed natural gas units and solar PV arrays will produce an average of 2.72 MW of electricity throughout the year,[21] and the existing diesel generators at Iona College will provide a maximum of 1.64 MW of backup power in emergency situations.

The natural gas generators have a nameplate capacity of 1.6 MW and 1.5 MW and will operate nearly continuously. Assuming a capacity factor of 85%, the natural gas units will produce approximately 11,900 megawatt hours (MWh) and 11,150 MWh, respectively, over the course of the year. If a major power outage occurs, the natural gas units can produce a maximum of 38.4 MWh and 36 MWh (each generators' full nameplate capacity) of electricity per day, respectively. Peak production would provide over 100% of the microgrid's average daily demand. Assuming a heat rate of 9.5 MMBTU/MWh,[22] the natural gas units will incur a fuel cost of approximately $53/MWh.[23]

Limited by weather conditions and natural day-night cycles, each 0.3 MW solar PV array is expected to produce approximately 368 MWh per year. Because many outages are caused by severe weather events, solar panels cannot be relied upon to provide energy during emergency outages without supplementary battery storage. However, each solar array will produce an average of around 1.01 MWh of electricity per day, which represents 6.2% of average daily electricity demand from microgrid-connected facilities. Maintenance costs for each solar array will be around $6,000 per year,[24] which means the total cost of producing solar electricity will be about $34/MWh.

The existing diesel generators at Iona College will be used only in emergency situations when the microgrid requires a black start or when the proposed natural gas units and solar arrays are not producing sufficient electricity to meet aggregate demand. The combined nameplate capacity of the diesel generators at Iona College is 1.64 MW. This generation capacity could be vital in emergency situations, or when the solar array or natural gas units go offline for maintenance. The Booz Allen team predicts the natural gas units will operate approximately 20% of the time during the 2.67 hours of larger grid outage per year,[25] for a total of approximately 2.5 MWh of power per year.[26] The collection of diesel generators requires around 116.4 gallons of fuel per

[21] 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).
[22] 2013 EIA average for natural gas fired Gas Turbine (http://www.eia.gov/electricity/annual/html/epa_08_02.html).
[23] Price of natural gas: $5.74 per Mcf (average Con Ed supply price from 2013-2015).
[24] Annual fixed O&M cost: $20/kW per year (NREL, http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html).
[25] Grid outage data from DPS 2013 Electric Reliability Performance Report (Con Ed average CAIDI).
[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 the New Rochelle microgrid was 1.345 MW. The proposed natural gas generators can provide a maximum of 3.1 MW of generation. Load is expected to exceed the natural gas generators' maximum

hour of operation.[27] In the event of a major power outage, these generators could produce a maximum of 39.36 MWh/day—however, assuming the natural gas and solar will require backup power during only 20% of emergency outage hours, this figure drops to 7.87 MWh/day. See Tables 27 and 28 for a detailed list of all proposed and existing distributed energy resources in New Rochelle.

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.

[27] Diesel Consumption Rate: 0.071 Gallon/kWh, average fuel consumption of the diesel generators.

Table 27. Distributed Energy Resources – Iona College

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 0.534 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)	Average 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 - New Natural Gas Generator	Iona College	Natural Gas	1.6	11,913.6	32.64	38.4	9.26 Mcf	9.5 MMBTUs
DER2 - New Solar Panel	Iona College	Sunlight	0.3	367.9	1.008	2.4[28]	N/A	N/A
DER3 - Existing Diesel Generator	Iona College	Diesel	0.23	0.117	1.104	5.52	71 Gallons[29]	9.83 MMBTUs[13]
DER4 - Existing Diesel Generator	Iona College	Diesel	0.285	0.145	1.368	6.84	71 Gallons	9.83 MMBTUs
DER5 - Existing Diesel Generator	Iona College	Diesel	0.1	0.051	0.48	2.4	71 Gallons	9.83 MMBTUs
DER6 - Existing Diesel Generator	Iona College	Diesel	0.075	0.038	0.36	1.8	71 Gallons	9.83 MMBTUs

[28] Based on 10 hours of production (daylight) at 80% of capacity.

[29] All ten diesel generators efficiencies' were averaged together for simplicity.

Distributed Energy Resource Name	Location	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Average Daily Production During Major Power Outage (MWh)	Potential Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh	
							System fuel	Units of MMBTUs
DER7 - Existing Diesel Generator	Iona College	Diesel	0.15	0.076	0.72	3.6	71 Gallons	9.83 MMBTUs
DER8 - Existing Diesel Generator	Iona College	Diesel	0.075	0.038	0.36	1.8	71 Gallons	9.83 MMBTUs
DER9 - Existing Diesel Generator	Iona College	Diesel	0.125	0.063	0.6	3	71 Gallons	9.83 MMBTUs
DER10 - Existing Diesel Generator	Iona College	Diesel	0.125	0.063	0.6	3	71 Gallons	9.83 MMBTUs
DER11 - Existing Diesel Generator	Iona College	Diesel	0.35	0.178	1.68	8.4	71 Gallons	9.83 MMBTUs
DER12 - Existing Diesel Generator	Iona College	Diesel	0.125	0.063	0.6	3	71 Gallons	9.83 MMBTUs

Table 28. Distributed Energy Resources – United Hebrew

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

Distributed Energy Resource Name	Location	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Average 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 - New Natural Gas Generator	United Hebrew	Natural Gas	1.5	11,165.6	30.6	36	9.26 Mcf	9.5 MMBTUs
DER2 - New Solar Panel	United Hebrew	Sunlight	0.3	367.9	1.008	2.4[30]	N/A	N/A

[30] Based on 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 continuously throughout the year (other than regularly scheduled maintenance), providing a constant level of load support. Although continuous operation will limit the natural gas generators' ramp-up capability during peak demand events, it will maximize revenue for the owners. The existing diesel backup generators will also be available to reduce peak load in cases of extreme demand. See Tables 29 and 30 for the maximum generation capacities of the proposed and existing DERs.

The proposed solar arrays will be their most productive on the days with greatest irradiance when peak demand events are common, thus providing peak load support when it is most needed. Each of them will provide around 0.042 MW of load support on average over the course of a year (including capacity factors). However, because generation depends on weather conditions and time of day, the solar arrays are not a reliable source of peak load support.

Table 29. Distributed Energy Resource Peak Load Support – Iona College

Table shows the available capacity and impact of the expected provision of peak load support from each DER. Existing generators were not included because they are not expected to generate electricity outside of emergency island mode situations.

Distributed Energy Resource Name	Location	Available Capacity (MW)	Does distributed energy resource currently provide peak load support?
DER1 – Iona College	Natural Gas Generator at Iona College	Maximum of 1.6	No
DER2 – Iona College	Solar PV array at Iona College	Maximum of 0.3	No

Table 30. Distributed Energy Resource Peak Load Support – United Hebrew

Table shows the available capacity and impact of the expected provision of peak load support from each DER. Existing generators were not included because they are not expected to generate electricity outside of emergency island mode situations.

Distributed Energy Resource Name	Location	Available Capacity (MW)	Does distributed energy resource currently provide peak load support?
DER1 – United Hebrew	Natural Gas Generator at United Hebrew	Maximum of 1.5	No
DER2 – United Hebrew	Solar PV array at United Hebrew	Maximum of 0.3	No

4.3.2 Demand Response

Demand response programs require facilities to curtail load or expand generation using generators in response to forecasted or real-time peak demand events on the larger grid. Entering island mode is the primary method for a microgrid to reduce load on the larger grid and thus participate in DR programs. The microgrid-connected generation and loads will be able to disconnect from the larger grid as a single point. Therefore, the microgrid should be able to participate in New York Independent System Operator (NYISO) and Con Ed's DR programs. A caveat to this DR islanding potential is that the natural gas units will be providing baseload generation, which excludes them from DR programs. The natural gas units will be excluded because microgrid islanding removes both load and generation from the grid, leaving the grid in a net neutral position. The microgrid will only enter island mode during emergency outages. Its ability to participate in DR programs is limited to reducing energy usage of individual loads, pending DR policy changes focused on microgrid application. The Project Team is currently assuming a high baseline level of operation for the natural gas generators and therefore negligible participation in DR programs.

4.3.3 Deferral of Transmission/Distribution Requirements

The 2.72 MW of average local generation produced by the DERs in addition to proposed distribution lines at Iona College and the United Hebrew Complex will, in part, reduce the amount of electricity imported from the Con Ed power lines, which will 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,[31] they can only transmit a limited amount of power. As demand for electricity in New Rochelle and Westchester increases, the microgrid may defer the need for new lines.

4.3.4 Ancillary Service

None of the existing and proposed generation resources in New Rochelle will participate in ancillary services markets. Although the natural gas generators can change output quickly enough to qualify for some paid NYISO ancillary service programs, it will not have sufficient capacity to participate. Most paid NYISO ancillary service programs require at least 1 MW of output regulation, which represents about two thirds of each natural gas generators' maximum output. If the natural gas generators runs at projected levels, they will almost never have the minimum regulation capacity available.

Although the natural gas unit will not participate in paid NYISO ancillary service programs, it will provide many of the same ancillary services to the local New Rochelle grid. For example, the natural gas unit will provide frequency regulation as a by-product of its operation. The New Rochelle 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 use natural gas generators instead of combined head and power units. Therefore there is no proposed CHP unit for the New Rochelle microgrid.

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

4.3.6 Environmental Regulation for Emission

The microgrid's generation assets will drive a net 4,024 $MTCO_2e$ (metric tons CO_2 equivalent) increase in GHG emissions in New Rochelle as compared to the New York State energy asset mix. The proposed generation assets will produce around 23,820 MWh of electricity per year. The natural gas units and backup diesel generators will emit approximately 12,670 $MTCO_2e$ per year, [32] while the solar arrays emit none. The current New York State energy asset mix would emit approximately 8,645 $MTCO_2e$ to produce the same amount of electricity.[33] The microgrid's generation assets will therefore result in a net increase in emissions by 4,024 $MTCO_2e$.

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 units are defined as "small boilers" by NYS Department of Environmental Conservation (NYS DEC) limits (fuel input of 10-25 MMBTU/hour). The NYS DEC is currently developing output-based emissions limits for distributed energy resource assets. These limits on SO_2, NO_x, and particulate matter (to be captured in 6 NYCRR Part 222) should be published in late 2015 or early 2016. The main source of emissions regulations for small boilers is currently the EPA 40 CFR part 60, subpart 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 31 catalogs the CO_2, SO_2, NO_x, and Particulate Matter (PM) emissions rates for the natural gas and diesel generators.

[32] Natural Gas Generator Emissions Rate: 0.55 MTCO2e/MWh (EPA, http://www3.epa.gov/chp/documents/faq.pdf).
NG generator Emissions Rate: 0.51 $MTCO_2e$/MWh (assuming 117 lb CO_2e per MMBTU; EIA, http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11).

[33] Assuming an asset mix of 15% coal, 31% natural gas, 6% oil, 17% hydro, 29% nuclear, 1 % wind, 1% sustainably managed biomass, and 1% "other fuel". This adds up to around 0.36 $MTCO_2e$/MWh. Info from EPA (http://www3.epa.gov/statelocalclimate/documents/pdf/background_paper_3-31-2011.pdf).

Table 31. Emission Rates

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

Distributed Energy Resource Name	Location	Emissions Type	Emissions Per MWh (Metric Tons/MWh)
DER1 – Iona College	Natural Gas generators at Iona College	CO_2	0.553
		SO_2	0.0000067[34]
		NO_x	0.00055[35]
DER1 – United Hebrew	Natural Gas generators at United Hebrew	CO_2	0.553
		SO_2	0.0000067[36]
		NO_x	0.00055[37]
DER3 - DER12 – Backup Diesel Generation	Iona College (backup generation)	CO_2	0.7196[38]
		SO_2	0.1911[39]
		NO_x	2.9074
		PM	0.2046

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 Iona College and the United Hebrew Complex substations 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 both substations as well as the smaller 13.2 kV distribution feeders.
- Automated breakers installed throughout New Rochelle 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 installed capital cost of the equipment at Iona College is estimated to be $740,000 for the Iona College substation, and $480,000 for required manholes at Iona College.[40] There will be an additional cost of $200,000 for overhead powerline installation or $1.76 million if the powerlines

[34] Emissions calculator, EPA.
[35] EPA, http://www3.epa.gov/chp/documents/faq.pdf.
[36] Emissions calculator, EPA.
[37] EPA, http://www3.epa.gov/chp/documents/faq.pdf.
[38] 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).
[39] Michigan Department of Environmental Quality; Environmental Science and Services Division. "Potential to Emit, Diesel Fired Generator Calculation Worksheet."
[40] Three manholes at $160,000 each (Elizabeth Cook - Con Ed).

are installed underground.[41] The installed capital cost of the equipment at the United Hebrew Complex is estimated to be $183,000 for the United Hebrew Substation. There will be an additional cost of $70,000 for overhead powerline installation or $600,000 if the powerlines are installed underground.[42] The cost of the IT communication cabling for the entire microgrid will be $30,000.

The 1.6 MW natural gas generator, 1.5 MW natural gas generator, and the two 0.3 MW solar PV arrays will carry installed costs of $2.08 million, $1.95 million and $1.44 million, respectively.[43] This brings the total installed capital cost to approximately $7.17 million,[44] not including interconnection fees and site surveys. See Tables 32Table-34 below for estimated installed costs for each microgrid component.

The team estimates nearly every piece of microgrid equipment has a useful lifespan of 20 years. The only component with a shorter lifespan is the microgrid control system (Siemens SICAM PAS or equivalent), which will be replaced by more advanced software after seven to eight years.

Tables 32 and 33 detail capital cost of the upgrades necessary to the Iona College and United Hebrew Complex substations. The substation includes equipment such as the microgrid control system, IED, and centralized generation controls that will allow the operator and electronic controllers to manage the entire microgrid.

[41] Cost estimate provided by Travers Dennis - Con Ed.
[42] Ibid.
[43] Natural Gas Generators Capital Cost: $1,300/kW (Siemens natural gas generators estimate).
Solar PV Capital Cost: $2,400/kw (Siemens Solar PV estimate).
[44] If overhead powerline installation is used, and $9.26 million if underground powerline installation is used.

Table 32. Capital Cost of Iona College Substation

Table displays the estimated costs and lifespan of the equipment associated with the Iona College Substation of the microgrid.

Iona College Substation				
Capital Component	**Quantity**	**Installed Cost ($) (+/ 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
Microgrid Control System (Siemens SICAM PAS or equivalent)	1 Primary 1 Back-up	$50,000 (total)	7 - 8	Control system responsible for operating the microgrid sequencing and data concentration under all operating modes.
Microgrid Control Center (Siemens MGMS or equivalent)	1	$300,000	20	Provides data trending, forecasting, and advanced control of generation, loads and AMI/SCADA interface, interface to NYISO for potential economic dispatch.
Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay)	8	$200,000	20	New breakers/switches at eight distribution load feeders to isolate microgrid from the utility feed. Eighth breaker to separate the non-critical/non Iona North St addresses from microgrid.
Automated Load Circuit Breakers (Siemens 7SJ85 relay)	4	$40,000	20	New switch at Iona College load circuit breakers for remote monitoring/control to enable load shedding and generator sequential loading
Generation Controls (OEM CAT, Cummins, etc.)	11	$22,000	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 MGMS for forecasting
WiMax Base Station	1	8,000	20	Located near microgrid control cabinet. Communicates wirelessly with WiMax subscriber units for remote control and monitoring of breakers and switches. Should be installed at high location.
WiMax Subscriber Units	5	10,000	20	Each subscriber unit can communicate back to the WiMax base station for MGMS/MCS 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	-	$85,000	-	Installation of capital components in the microgrid

Table 33. United Hebrew Substation

Table displays the estimated costs and lifespan of the equipment associated with the United Hebrew Substation of the microgrid.

United Hebrew Substation				
Capital Component	Quantity	Installed Cost ($) (+/ 30%)	Component Lifespan (Years)	Purpose/Functionality
Microgrid Control System (Siemens SICAM PAS or equivalent)	1 Primary 1 Back-up	$50,000 (total)	7 - 8	Control system responsible for operating the microgrid sequencing and data concentration under all operating modes.
Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay)	2	$20,000	20	Update existing switches at two distribution load feeders to isolate microgrid from the utility feed remotely. Separate Con Ed line to Cedar Street Substation from microgrid.
Automated Load Circuit Breakers (Siemens 7SJ85 relay)	3	$15,000	20	New switch to Willow Tower and upgrade existing load circuit breakers to Low-Savin Residence and United Hebrew Geriatric Center for remote monitoring/control to enable load shedding and generator sequential loading
Automated PME (Siemens 7SJ85 multi breaker control relay)	1	$20,000	20	Pad mount enclosure (PME) with two switches and two fuses. To be updated to be automated with remote control relay capable of controlling both switches. Current sensing on utility infeed allows for ability to initiate emergency microgrid mode.
Generation Controls (OEM CAT, Cummins, etc.)	1	$2,000	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 MGMS for forecasting
WiMax Base Station	1	$8,000	20	Located near Microgrid Control Cabinet. Communicates wirelessly with WiMax subscriber units for remote control and monitoring of breakers and switches. Should be installed at high location.
WiMax Subscriber Units	5	$10,000	20	Each subscriber unit can communicate back to the WiMax base station for MGMS/MCS 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	-	$33,000	-	Installation of capital components in the microgrid

Table 34. 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
1.6 MW Natural Gas Unit	1	$2,080,000	20	Generation of electricity
1.5 MW Natural Gas Unit	1	$1,950,000	20	Generation of electricity
0.3 MW Solar PV arrays	2	$1,440,000	30	Generation of electricity

The microgrid IT infrastructure will also require Cat-5e Ethernet cables for communication between distribution switches, generation switchgear, PV inverters, and network switches. The design uses Cat-5e cabling, including RJ-45 connectors at $0.60 per cable.[45] The total installation cost of cabling is approximately $5.65 per foot.[46] The Project Team will use the existing cabling infrastructure to install the communications cables, thereby avoiding the high costs of trenching the proposed lines. The estimated total cost for the microgrid IT infrastructure is around $30,000.[47]

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 at Iona College $200,000 for an overhead installation and $1.76 million for an underground installation.[48] Additionally, the Iona College requires three manholes at the cost of $160,000 each.[49] At United Hebrew the approximate cost of building these new lines is $70,000 for an overhead installation and $600,000 for an underground installation.[50]

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.

[45] Commercially available RJ-45 connectors, $0.30 per connector.

[46] Installation costs for Cat5e: $5.45/ft.
Component cost for Cat5e: $0.14/ft (commercially available).

[47] The Project Team estimated ~5120 feet of Cat5e cable will be necessary.

[48] The Project Team has determined that approximately 3,250 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.

[49] Three manholes at $160,000 each (Elizabeth Cook - Con Ed).

[50] The Project Team has determined that approximately 1,110 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.

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 35 below.

Table 35. 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 ($)[51]	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 units will cost around $323,000 per year.[52] The microgrid will also incur $19,500/year in total costs for annual fixed system service agreements for the solar PV arrays and backup diesel generators.[53]

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. For example, the natural gas units will require capital for fuel, consumable chemicals, and other operating expenses. The diesel usage of the backup generators is difficult to predict because they will be used only during some emergency outage situations.

51 Estimates developed by Booz Allen Project Team and independent consultant.
52 Natural Gas O&M: $0.014/kWh. (Siemens).
53 Solar PV array ($20/kW-year) and $4.60/kW-year for backup diesel generators (Electric Power Research Institute, "Costs of Utility Distributed Generators, 1-10 MW").

The solar PV arrays will not require fuel to operate, and it should not require service outside of the normally scheduled maintenance. Normally scheduled maintenance should cost approximately $20/kW per year.[54]

Annual service for all non-DER microgrid components will cost approximately $70,000 per year.[55] Table 36 outlines all fixed operations and maintenance (O&M) costs associated with annual operation of the microgrid.

Table 36. Fixed Operating and Maintaining 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
~ $323,000 including both fixed and variable costs	Natural Gas Unit Service Agreement– Annual costs of maintenance and servicing of unit
~ $12,000 total	Solar PV System Service Agreement – Annual costs of maintenance and servicing of unit
~ $7,500 total	Backup Diesel Generators – 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 generators will have a continuous supply of fuel unless the pipeline is damaged or destroyed. The natural gas generators can operate continuously given properly functioning gas pipelines, therefore there is effectively no maximum operating duration for the natural gas generators 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 diesel generators at Iona College will require a total of 116.4 gallons of diesel fuel per hour at full load. The Iona College generators have about 4,600 gallons of diesel storage installed, so at a 100% level of output this generator can operate for 55 hours without replenishing its fuel supply.

The solar PV array does not require fuel for operation, but its output depends on weather and time of day. Tables 37 and 38 shows the fuel consumption and operating times for all of the microgrid DERs.

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

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

Table 37. Maximum Fuel Operating Time for Distributed Energy Resource – Iona College

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 – Iona College	Natural Gas generators at Iona College	Natural Gas	N/A	N/A	Mcf
DER2 – Iona College	Solar PV arrays at Iona College	N/A	N/A	N/A	N/A
DER3 - DER12 – Backup Diesel Generation	Iona College (backup generation)	Diesel	55	4,600[56]	Gallon

Table 38. Maximum Fuel Operating Time for Distributed Energy Resource – United Hebrew

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 – United Hebrew	Natural Gas generators at United Hebrew	Natural Gas	N/A	N/A	Mcf
DER2 – United Hebrew	Solar PV arrays atnd United Hebrew	N/A	N/A	N/A	N/A

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

4.5.1 Backup Generation Cost during a Power Outage

The proposed generation will continue to provide baseload power in the event of an extended power outage with the natural gas generators being the most reliable and productive. They have nameplate capacities of 1.6 MW and 1.5 MW, respectively, and operating at 85% efficiency and could supply a combined average of 2.635 MW to the microgrid throughout the year. Because the natural gas generators will use natural gas from the pipeline as fuel, disruptions to its fuel source are unlikely. At maximum output during an outage, the natural gas units will generate approximately 38.4 MWh and 36 MWh per day, using around 355 Mcf (365 MMBTU) and 333 Mcf (342 MMBUT) respectively of natural gas. The natural gas generators 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.

[56] Used comparable generators to find average size of each fuel storage tank (http://www.machinerytrader.com).

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 outages occur due to high electricity demand during the most irradiated days of the year, the solar panels will be at their most productive and could provide up to 0.6 MW total of load support to the New Rochelle microgrid. Tables 39 and 40 shows all of the costs associated with operating the DERs during a power outage, including fuel and variable O&M costs.

The ten backup diesel generators will only come online when the natural gas unit and solar array do not provide sufficient power to Iona College when the microgrid is in islanded mode. The natural gas generator at Iona College can produce 1.6 MW at full capacity and the microgrid's average load at Iona College was 0.69 MW in 2014, therefore the natural gas generator and solar array should be capable of satisfying the microgrid's power demand in most situations. In the cases when the load peaks (1.94 MW in 2014) the backup diesel generators will be necessary; this will result in about 20% of total outage time, which translates to an average production of 7.87 MWh per day. The backup diesel generators will require around 560 gallons per day at this level of production. One-time startup costs or daily non-fuel maintenance costs for any of the diesel generators is not anticipated.

Table 39. Cost of Generation during a Power Outage – Iona College

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)	Power Outage 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 O&M)
						Quantity	Unit		
Iona College	DER1 - New Natural Gas Generator	Natural Gas	1.6	100%	38.4	355.5	Mcf	N/A	$2,500
Iona College	DER2 - New Solar Panel	Sunlight	0.3	14%	1.008[57]	N/A	N/A	N/A	$15
Iona College	DER3 - Existing Diesel Generator	Diesel	0.23	100%	5.52	391.9	Gallons	N/A	$1,535[58]
Iona College	DER4 - Existing Diesel Generator	Diesel	0.285	100%	6.84	485.6	Gallons	N/A	$1,902
Iona College	DER5 - Existing Diesel Generator	Diesel	0.1	100%	2.4	170.4	Gallons	N/A	$668
Iona College	DER6 - Existing Diesel Generator	Diesel	0.075	100%	1.8	127.8	Gallons	N/A	$501
Iona College	DER7 - Existing Diesel Generator	Diesel	0.15	100%	3.6	255.6	Gallons	N/A	$1,001

[57] 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.
[58] = Daily fuel cost during an outage + (Yearly O&M/365).

Location	Distributed Energy Resource	Energy Source	Nameplate Capacity (MW)	Power Outage 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 O&M)
						Quantity	Unit		
Iona College	DER8 - Existing Diesel Generator	Diesel	0.075	100%	1.8	127.8	Gallons	N/A	$501
Iona College	DER9 - Existing Diesel Generator	Diesel	0.125	100%	3	213	Gallons	N/A	$834
Iona College	DER10 - Existing Diesel Generator	Diesel	0.125	100%	3	213	Gallons	N/A	$834
Iona College	DER11 - Existing Diesel Generator	Diesel	0.35	100%	8.4	596.4	Gallons	N/A	$2,336
Iona College	DER12 - Existing Diesel Generator	Diesel	0.125	100%	3	213	Gallons	N/A	$834

Table 40. Cost of Generation during a Power Outage – United Hebrew

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)	Power Outage 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 O&M)
						Quantity	Unit		
United Hebrew	DER1 - New Natural Gas Generator	Natural Gas	1.5	100%	36	333.3	Mcf	N/A	$2,340
United Hebrew	DER2 - New Solar Panel	Sunlight	0.3	14%	1.008[59]	N/A	N/A	N/A	$15

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

4.5.2 Cost to Maintain Service during a Power Outage

There are no costs associated with switching the microgrid to island mode during a power outage other than the operational costs already accounted for in Tables 41 and 42. 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)

All of the microgrid supported facilities provide services (nursing or education) and housing to their tenants. For example, Iona College provides educational services to its 3,900 students and houses them as well. For estimates of the population served by each critical facility, see Tables 43 and 44.

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. Based on the portfolio of services that each facility provides and the electricity dependency of each service, Tables 41 and 42 provides an estimate of how effectively each facility can perform its normal services without electricity.

Table 41. Critical Services Supported – Iona College

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[60]	
		When Backup Power is Available	When Backup Power is Not Available
Iona College	~ 4,300[61]	0%	>90%

[60] 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).

[61] Combine total of faculty, staff, and enrolled students (http://colleges.usnews.rankingsandreviews.com/best-colleges/iona-college-2737).

Table 42. Critical Services Supported – United Hebrew

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[62]	
		When Backup Power is Available	When Backup Power is Not Available
United Hebrew Geriatric Center	~ 350[63]	0%	>90%
Willow Towers Assisted Living	~ 150	0%	>75%
Low Savin Residence	~ 150	0%	>75%

4.7 Industrial Economics Benefit-Cost Analysis Report

As follows is a direct cost-benefit analysis from Industrial Economics. IEc was hired by NYSERDA to conduct a benefit-cost analysis of each feasibility study. The benefit-cost analysis of the New Rochelle microgrid was delivered to the Project Team on February 18, 2016.

4.7.1 Project Overview

As part of NYSERDA's NY Prize community microgrid competition, the City of New Rochelle has proposed development of a microgrid that would serve four facilities in close proximity to one another on North Avenue and Pelham Road:

- Iona College, a local 4-year college with approximately 4,000 enrolled students
- The United Hebrew Geriatric Center, a nursing home and short-term rehabilitation center with approximately 296 residents.[64]
- Willow Towers Assisted Living, a 126-unit assisted living facility for ages 65 and older.[65]
- Soundview Senior Apartments (The Low Savin Residence), a 135-apartment independent living facility for ages 62 and older.[66]

The microgrid would be powered by four new distributed energy resources – a 1.6 MW natural gas unit, a 1.5 MW natural gas unit, and two 300 kW PV arrays. The town anticipates that the natural gas units and PV systems would produce electricity for the grid during periods of normal operation. The system as designed would have sufficient generating capacity to meet average

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[62] 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).

[63] United Hebrew website, accounts for residents and staff (http://www.unitedhebrewgeriatric.org/index.asp).

[64] http://www.unitedhebrewgeriatric.org/skalet_nursing_home.asp; http://nursing-homes.healthgrove.com/l/9227/United-Hebrew-Geriatric-Center.

[65] http://www.unitedhebrewgeriatric.org/assisted_living.asp.

[66] http://www.unitedhebrewgeriatric.org/independent_living.asp.

demand for electricity from the four 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.[67] It also calculates an annualized estimate of costs and benefits based on the anticipated engineering lifespan of the system's equipment. Once a project's cumulative benefits and costs have been adjusted to present values, the model calculates both the project's net benefits and the ratio of project benefits to project costs. The model also calculates the project's internal rate of

[67] This 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 PM2.5, 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.]

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.[68]

4.7.3 Results

Table 43 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 43. BCA Results (Assuming 7 Percent Discount Rate)

Economic Measure	Expected Duration of Major Power Outages	
	Scenario 1: 0 Days/Year	Scenario 2: 5.1 Days/Year
Net Benefits - Present Value	-$12,200,000	$221,000
Benefit-Cost Ratio	0.72	1.0
Internal Rate of Return	n/a	8.3%

[68] 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 5 and Table 44 present the detailed results of the Scenario 1 analysis.

Figure 5. Present Value Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

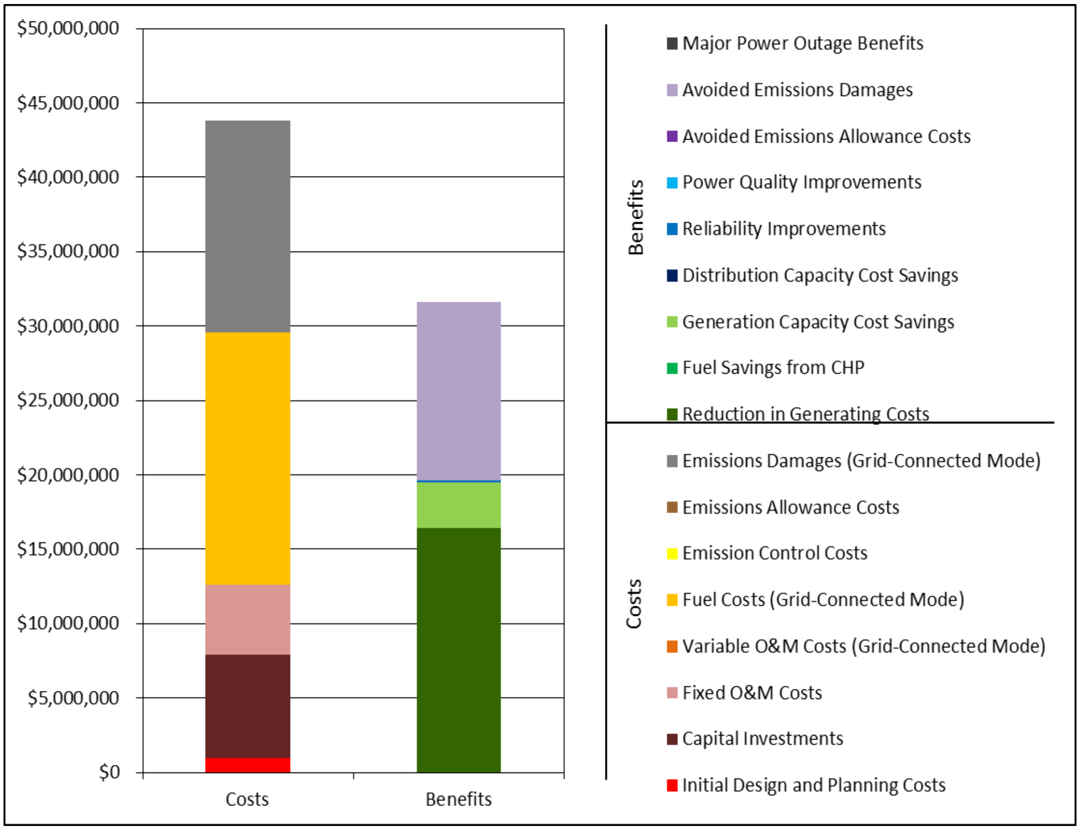

Table 44. Detailed BCA Results, Scenario 1

(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	$6,940,000	$577,000
Fixed O&M	$4,670,000	$412,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$17,000,000	$1,500,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$14,200,000	$927,000
Total Costs	**$43,800,000**	
Benefits		
Reduction in Generating Costs	$16,400,000	$1,450,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$3,110,000	$274,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$78,400	$6,930
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$8,080	$713
Avoided Emissions Damages	$12,000,000	$783,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$31,600,000**	
Net Benefits	**-$12,200,000**	
Benefit/Cost Ratio	**0.72**	
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 $6.9 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 and 1.6 MW natural gas units; the two 300 kW PV arrays; 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 $412,000. The present value of these O&M costs over a 20-year operating period is approximately $4.7 million.

Variable Costs

The most significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the system's primary generators. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the Project Team and projections of fuel costs from New York's 2015 State Energy Plan (SEP), adjusted to reflect recent market prices.[69] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $17 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 $930,000 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 $14.2 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 City of New Rochelle's proposed microgrid, the primary source of cost savings would be a reduction in demand for electricity from bulk energy suppliers, with a resulting reduction in generating costs. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $16.4 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. These reductions in demand for electricity from bulk energy suppliers would also result in avoided emissions of CO_2, SO_2, NO_x, and particulate matter, yielding emissions allowance cost savings with a present value of approximately $8,080 and avoided emissions damages with a present value of approximately $12.0 million.[70]

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.[71] 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 2.719 MW per year (the Project Team estimates no impact on distribution capacity). Based on this figure, the BCA estimates the present value of the project's generating capacity benefits to be approximately $3.1 million over a 20-year operating period.

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

[70] 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.

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

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. 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 $7,000 per year, with a present value of approximately $78,000 over a 20-year operating period. This estimate is calculated using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, and is based on the following indicators of the likelihood and average duration of outages in the service area:[72]

- System Average Interruption Frequency Index – 0.11 events per year.
- Customer Average Interruption Duration Index – 181.2 minutes.[73]

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.[74] 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.

Summary

The analysis of Scenario 1 yields a benefit/cost ratio of 0.72; i.e., the estimate of project benefits is approximately 75 percent of project costs. Accordingly, the analysis moves to Scenario 2,

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[72] www.icecalculator.com.
[73] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for Consolidated Edison.
[74] http://www.businessweek.com/articles/2012-12-04/how-to-keep-a-generator-running-when-you-lose-power#p1.

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.[75,76]

As noted above, the City of New Rochelle's microgrid project would serve four facilities: Iona College; United Hebrew Geriatric Center; Willow Towers Assisted Living; and Soundview Senior Apartments (The Low Savin Residence). The project's consultants indicate that at present, only Iona College is equipped with backup generators; the level of service these units can support is approximately 84 percent of the ordinary level of service at the college. Operation of these units costs approximately $11,000 per day. Should these units fail, the college 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 $17,000 per day. Similarly, United Hebrew Geriatric Center, Willow Towers Assisted Living, and Soundview Senior Apartments (The Low Savin Residence) could maintain service by bringing in portable generators, at a cost of approximately $5,800 per day, $4,600 per day, and $4,600 per day, respectively. In the absence of backup power – i.e., if the backup generator failed and no replacement was available – Iona College and United Hebrew Geriatric Center would experience at least a 90 percent loss in service capabilities, while Willow Towers Assisted Living and Soundview Senior Apartments (The Low Savin Residence) would experience at least a 75 percent loss in service capabilities.

[75] 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.

[76] 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 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:

- Iona College would rely on its existing backup generators, experiencing a 16 percent loss in service capabilities while the generators operate. If the backup generators fail, the facility would experience a 90 percent loss of service.
- United Hebrew Geriatric Center, Willow Towers Assisted Living, and Soundview Senior Apartments (The Low Savin Residence) would rely on portable generators, experiencing no loss in service capabilities while these units are in operation. If the portable generators fail, these facilities would experience a 90 percent loss in service effectiveness, a 75 percent loss in service effectiveness, and a 75 percent loss in service effectiveness, respectively.
- In all four 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 impact of a loss in service at these facilities is based on the following value of service estimates:

- For Iona College, a value of approximately $659,000 per day. This figure is based on an estimate of the college's total 2014 operating budget, pro-rated over a 365-day year.[77]
- For United Hebrew Geriatric Center, a value of approximately $112,000 per day. This figure is based on an estimate of the facility's capacity (296 beds) and state data on the average rate for nursing home care in the area ($377/patient/day).[78]
- For Willow Towers Assisted Living and Soundview Senior Apartments (The Low Savin Residence), a value of approximately $58,000 per day. This figure is based on the

[77] Tuition, room and board (http://www.iona.edu/Student-Life/Student-Financial-Services/Student-Accounts/Tuition-and-Fee-Schedule.aspx) cover approximately 84 percent of the total 2014 Operating Budget for Iona College (http://www.iona.edu/iona/media/Documents/About/Administrative%20Offices/SAC-Minutes/2014108.pdf). Note that this value is at best a rough approximation of the social welfare loss attributable to a loss of power at the college, as it does not account for the potential to reschedule lost class time when power is restored; the impact of disruptions in schedule on the productivity of students, instructors, or administrators; the effect of an extended outage on the cost of operating and maintaining the college; the value of research that an outage may impede; and other factors that would more accurately characterize the impact of a loss of service during an extended outage.

[78] 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.

approximate number of residents at these facilities (304) and the Annual Median Cost of Long Term Care for Outer New York City.[79]

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for the facilities of interest is approximately $830,000 per day.

Summary

Figure 6 and Table 45 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 below this figure, its costs are projected to exceed its benefits.

[79] https://www.genworth.com/corporate/about-genworth/industry-expertise/cost-of-care.html. 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.

Figure 6. Present Value Results, Scenario 2

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

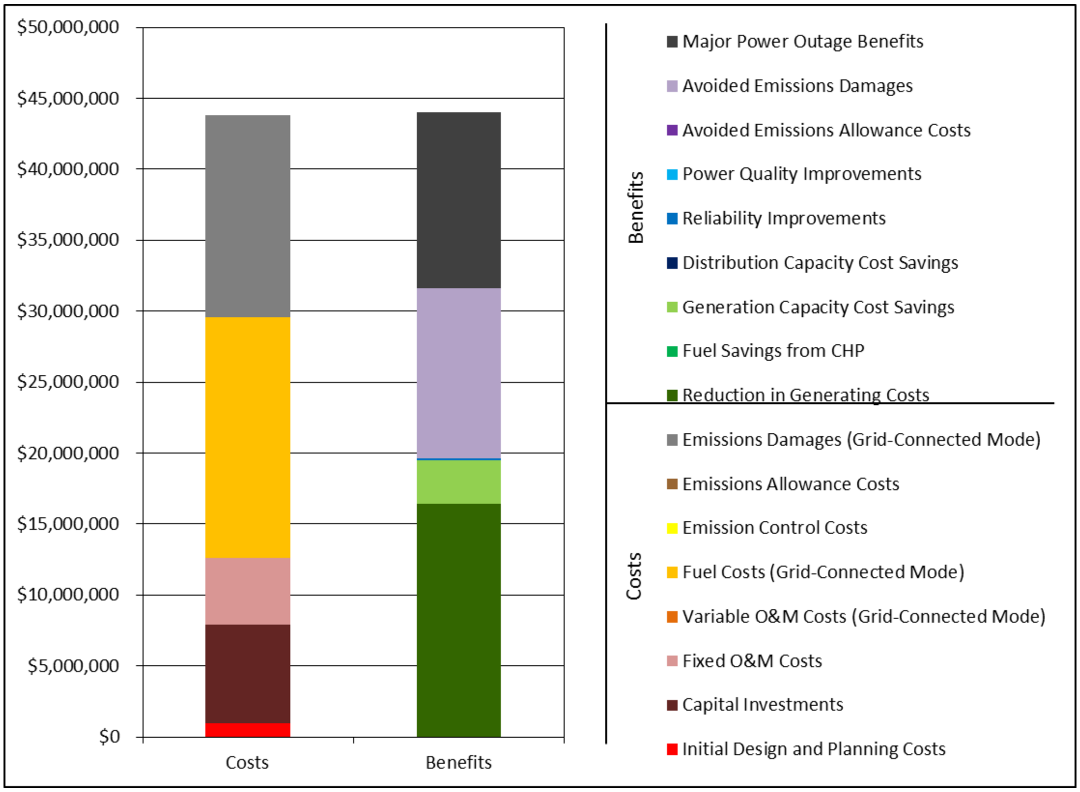

Table 45. Detailed BCA Results, Scenario 2

(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	$6,940,000	$577,000
Fixed O&M	$4,670,000	$412,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$17,000,000	$1,500,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$14,200,000	$927,000
Total Costs	**$43,800,000**	
Benefits		
Reduction in Generating Costs	$16,400,000	$1,450,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$3,110,000	$274,000
Transmission & Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$78,400	$6,930
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$8,080	$713
Avoided Emissions Damages	$12,000,000	$783,000
Major Power Outage Benefits	$12,400,000	$1,100,000
Total Benefits	**$44,000,000**	
Net Benefits	**$221,000**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**8.3%**	

The Project Team assumed an electricity sales price of $0.073 per kWh in New Rochelle. 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 New Rochelle, the Dunwoodie LBMP is $39.16 per MWh[80], 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

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

Project Team and by IEc. The Project Team is unaware of any community microgrid business model or generation set that is financially self-sufficient at the LBMP.

5. Summary and Conclusions

The Booz Allen team has assembled the necessary data for an independent cost-benefit analysis of the New Rochelle microgrid. The team assembled concrete cost and load data wherever possible and filled knowledge gaps with research-based assumptions. The proposed DERs will provide enough energy for the New Rochelle microgrid's connected facilities and will represent a net positive value investment, using current-day natural gas prices.

5.1 Lessons Learned and Areas for Improvement

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

The development of the New Rochelle microgrid proposal yielded several important issues to be addressed moving forward and lessons that can inform future microgrid development in the community. New Rochelle's government supports the microgrid project and has been 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 City, Con Ed, and the Project Team are comfortable.

The City of New Rochelle has a wide variety of critical and important facilities and, like much of the rest of downstate New York, has dealt with several severe weather events that have negatively impacted electric utility service in the area. At a first pass, New Rochelle is an excellent candidate for the development of a community microgrid, and coupled with the relatively high electricity prices of Westchester County, a location in which a microgrid is financially feasible to develop. The original mix of facilities in New Rochelle included a wide variety of public, medical, commercial, and residential uses, any subset of which would have created a strong community microgrid. As the Project Team engaged with Con Ed to downselect the facilities and develop the required infrastructure and new one-line diagrams, it became apparent that the local electrical infrastructure would not support a wide ranging community microgrid. Constrained by these factors, the Project Team is unable to propose a more cohesive, physically contiguous microgrid. If Con Ed loosens the restrictions on how extensively a community microgrid may overlay existing infrastructure, the opportunities for including further facilities will grow.

Generation options in the New Rochelle 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 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 important to maintaining the character of Iona College. 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.

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 New Rochelle relies on rebates and incentives that may not be available in the long term. And while expanding the footprint is theoretically feasible, Con Ed does not desire to do so at this time.

The New Rochelle 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 power purchase agreement, selling power to Con Ed's main grid. This structure was proposed because it is viable under current policy[81]; 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 Qualifying Facility designation or, absent that change, if the PSC were to provide affirmatively lightened regulation[82] for primarily natural-gas fired projects. The proposed New Rochelle project may be enjoined from a QF-like regulatory treatment given the distance between the facilities and the aforementioned natural gas generation solution.

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,

[81] Under existing law and Commission guidance, the New Rochelle 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).

[82] 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.

which would 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 additional revenue may potentially be generated through participation in demand response programs.

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.

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 New Rochelle, the location of critical and important facilities relative to the feeder network and Con Ed's preferred, small footprint was restrictive. These conditions contributed to the decision to propose physically and electrically separate clusters of facilities and, in effect, create two separate campus-style microgrids. In effect, there are communities in the State that are not well suited for community microgrids at this time and every effort should be made to focus resources on those that are more electrically flexible.

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. New Rochelle has relatively little space available for solar PV; indeed, the only open spaces within the footprint are campus open spaces at Iona College and various, small roofs at Iona and United Hebrew that cannot support large scale solar installations.

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 New Rochelle to justify the construction of a CHP unit, and the project financial feasibility reflects this absence of steam revenue. And 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, particularly with larger loads seen at Iona College and United Hebrew.

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. 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. New Rochelle is well positioned for this operational structure; however, 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 Feasibility Study, Con Ed informally communicated that 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 New Rochelle, as mentioned in Section 3.3, 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. In New Rochelle, the greater constraint was the availability of critical and important facilities in physical and electrical proximity and there is a limit to how much of a feeder a microgrid may control. 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 New Rochelle footprint, which limits the design proposal to the two relatively contained clusters. 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. New Rochelle, 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 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 New Rochelle, 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 need 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. This is especially true in regions with relatively low electricity costs. Additionally, many communities that require improvements to the grid for reliability and resilience and are lower income communities, which creates the added challenge of making them harder to pencil out financially as the community cannot afford to pay extra to ensure reliability. The projects with the least advantageous financials are often those needed most by the community. This gap is not easily bridged without further subsidization from the State.

5.2 Benefits Analysis

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

5.2.1 Environmental Benefits

New York State's 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 many peaking assets which come online when statewide demand is high. When coupled with the proposed solar PV array, the New Rochelle microgrid moves New York towards a clean, distributed energy future. Moreover, the microgrid obviates the need for the extensive diesel fired back up at Iona College, replacing it with solar and natural gas generated electricity.

5.2.2 Benefits to Local Government

The City 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 four facilities that provide critical and important services to the community, including a large shelter facility in Iona College and a collection of residential care and medical facilities at United Hebrew. The availability of these facilities in an emergency situation will provide public safety benefits to the community. The Project Team met with the community by phone on March 10th to provide a summary of project analyses and a recommended path forward.

5.2.3 Benefits to Residents of New Rochelle

Residents of New Rochelle stand to gain from access to shelter and emergency services during an outage on the grid. In addition, life-support services at United Hebrew Complex will be supported by the microgrid. Supporting the resilience of a residential 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 New Rochelle 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 New Rochelle 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 Statement of Work for this contract.

The primary risk of the New Rochelle microgrid project is financial; without grant funding or a change in regulatory treatment, project economics are unfavorable. The current proposal with four facilities across the two clusters 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 and lack of steam sales 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 become involved in local energy generation and distribution and will foster greater awareness of these issues. Finally, the project would demonstrate the widely distributed benefits of microgrids paired with distributed energy resource assets. The utility will see increased grid performance, customers will see stabilized electricity prices provided by a more reliable grid system, and the community will reap the positive benefits of living in and around the microgrid.

Path Ahead. The New Rochelle microgrid as proposed may ultimately be viewed by NYSERDA as two campus-style microgrids rather than an integrated community microgrid. As has been described in this document, the realities of the feeder system and critical facilities in the community dictated the technical proposal, with the two sections of the microgrid representing the Project Team's effort to meet the required features of a community microgrid within the context of NY Prize.

Ultimately, the City, and the respective facilities, may be better off pursuing independent, campus-style microgrids at each location, with the possibility of extending the footprint as nearby facilities evolve and more attractive community microgrid facilities become available. At the United Hebrew Complex, there is extensive commercial activity in the immediate vicinity and, while the Project Team was unable to identify a critical service provided by these business, it may be in the City's interest to pursue a microgrid that includes the gas stations, restaurants, and other commercial services nearby. This would likely not enhance the project in the eyes of NYSERDA and NY Prize, however given the high electricity costs in the region, the right mix of generation and load could yield a financeable project for the City at low interest rates and for the public good.

At Iona College, already a singular campus, it would be in their financial and electric reliability interest to install base-load natural gas generation, saving costs on energy purchases while decreasing reliability on the Con Ed grid in times of an outage. If a steam-off-taker can be identified, the installation would qualify for potentially lucrative rebates from the state. Opportunities to pair storage with solar installation may become available as the price of both continues to decline and the market for battery-based grid services, such as demand response and frequency regulation matures. Iona College could choose to incorporate a microgrid controller and necessary switches at construction or at a later date, perhaps building to a formal microgrid installation on the savings realized on new electricity sources.

Increasing solar penetration and energy efficiency programs are a no-regret policy for the City and, working with Con Ed and the State, could set the groundwork for larger and longer term investments. Con Ed and NYSERDA offer several rebate and incentive programs that the proposed facilities may take advantage of, and the City should encourage other facilities to do the same. Among these are a continuation of LED upgrades at Iona, and a switch from fluorescent bulbs to LEDs at United Hebrew. This switch could save ~50% on lighting electricity compared to fluorescents and up to 90% compared to incandescent bulbs. Moreover, the residential components of both Iona and United Hebrew may be eligible for appliance rebates from Con Ed and Energy Star, decreasing both near term energy costs as well as decreasing the size of required generation should either complex move towards a microgrid. The separate paths forward for Iona College and United Hebrew can, and should, be pursued simultaneously by the responsible parties. The City and State's role in facilitating the improvements in grid resilience will remain, and the opportunities beyond a fully integrated, NY Prize eligible microgrid discussed in this report are all viable next steps.

Leveraging existing Con Ed EE programs to reduce load at existing facilities and seeking to qualify facilities for NYSERDA funded EE programs could bring significant subsidies to the community.

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 have 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.

Appendix

With fully executed non-disclosure agreements (NDAs), metering data for one full year was provided via Con Ed's on-line portal. For loads less than 500 kW, no interval data is available from Con Ed; therefore, a simulator was used to more accurately profile typical 24-hour load curves for each facility. The profiles were included in this feasibility study to show which facilities have highest and lowest load demands at different times of the day. Analyzing these load demand curves has allowed the team to develop a better overall understanding of the generation capacity needed to sustain the microgrid. 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 CONSOLIDATED EDISON